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National
Electric Light Association

THIRTY-FIFTH CONVENTION

VOLUME III

Power Transmission Sessions
Technical Sessions

Papers, Reports and Discussions

SEATTLE, WASH.
JUNE 10-13, 1912

Published by Order of the Executive Committee

The James Kempster Printing Co.
New York City

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WITH SYNOPSIS OF PAPERS

ABBOTT, W. L., Chairman. *Report of the Committee on Underground Construction:* The report is the result of investigations based upon inquiries sent to a number of the larger operating companies in this country. It specifically considers the following items: Alternating-current underground distribution; manhole construction; electrolysis; and high-tension cable data and specifications. Replies from twelve large operating companies pertaining to alternating-current underground distribution are grouped in a table for comparison. The manhole practise of eleven companies is presented in tabular form. Tables and curves show manhole costs. Elaborate data on high-tension cables is also presented. Probably the most important work done by the committee was the collecting of information relating to electrolysis of sub-surface structures. The committee first sent out a list of nineteen questions to all the member companies in cities having a population above 100,000. Definite and complete replies were received from companies operating in twenty-nine of the principal cities, and these are summarized in tabular form.
Discussion by Elden, Wilson. 611 to 656

BALLINGER, HON. R. A. *Address:* The former Secretary of the Interior delivered an address on the best means of developing our natural resources. A few years ago no classification of public lands in relation to water-power sites was known of, but later it became one of the programs of the conservation movement. Originally the public domain was under the jurisdiction of Congress, whereas it is now controlled by the executive branch of the Government. The doctrine of conservation laid down by the extremists is most impractical. The power sites that have already passed under private ownership exceed in total size the sites which now remain in the public domain. It would therefore be preferable for the national Government to yield its control at once to the States, thus allowing each locality to regulate is own development. A bill was introduced in Congress in 1910, to bring this about, but it met at once with the antagonism of the progressives, who were opposed to it for the reason that it would do away with the bureaucracy, and loosen their grip on the public domain. The withholding of power sites at the present time is a waste, and the national resources should unquestionably be thrown open to immediate development and exploitation for the benefit of the whole country. 109 to 119

BLOOD, W. H., JR., Chairman. *Report of the Committee on Grounding Secondaries:* The report calls attention to the fact that the subject of grounding secondaries of alternating-current systems has received extensive consideration for several years past, and states that the various bodies interested in the matter, including the American Institute of Electrical Engineers, the Association of Edison Illuminating Companies, the National Electrical Inspectors' Association and the National Electric Light Association, have at last agreed upon the policy of grounding. At a conference held in New York on March 12 of this year it was unanimously voted to recommend to the electrical committee of the National Fire Protection Association certain changes in Rule 15 of the National Electrical Code. The

recommended changes provide that transformer secondaries of distributing systems must be grounded when the maximum difference of potential between the grounded point and any other point in the circuit does not exceed 150 volts. If no neutral point or wire is accessible, one side of the secondary circuit must be grounded. Where the maximum potential difference exceeds 150 volts, grounding may be permitted. Water companies and municipal departments in charge of water-works are urged to allow the attaching of ground wires to their piping systems, without fear that damage will result. At a meeting of the electrical committee of the National Fire Protection Association, held on March 22 of this year, it was voted to approve these recommendations and to present them at the 1913 meeting for the revision of the code.

Discussion by Osgood, Faulkner. 308 to 313

Bushnell, O. J., Chairman. *Report of the Committee on Meters:* One of the greatest existing difficulties lies in securing properly trained metermen. It was considered important to compile a handbook which would deal with meter matters in a simple, practical manner, appealing to the class of men obtainable for handling the installation, maintenance and testing of meters. Accordingly, the committee compiled the Electrical Meterman's Handbook, which is now available for members of the Association. The handbook includes all valuable information contained in the recent published reports of the Meter Committee, and also such parts of the Meter Code as have a bearing on the practical operation of the meter department. The committee has given attention during the year to the standardization of meter design and has secured the consent of several manufacturers to the adoption of a simple standard form of meter dial plates. The need of a much cheaper meter for very small consumers is pointed out. A number of additions to the Meter Code presented at the last Edison convention are submitted with this report as an appendix. Illustrated.

Discussion by Rhodes, Cowles, Northmore, Jamieson, Osgood, Seaman, Vaughen. 250 to 285

Campbell, R. E., and M. D. Cooper. *The Proper Lamp for a Circuit:* The most important function of the central station is to obtain a profitable income by furnishing its customers with satisfactory light, which implies proper intensity and quality, with minimum fluctuation and maximum economy. The question of the proper lamp for a circuit can be referred to the value and variations of one quantity—voltage. But the voltage at which energy is supplied to the customer depends upon the conditions surrounding plant operation, the transmission of energy and the translation of this energy into light. Out of eighty-two of the smaller central stations visited by the authors, only twenty-five used any form of automatic regulator for controlling the generator voltage. Another subject investigated was the accuracy of station voltmeters, and it was found that there is room for much improvement. The subject of distribution systems is discussed in some detail, with special reference to regulation, and typical regulation curves for smaller lighting transformers are presented. The relation of voltage to revenue is illustrated by tables and curves. Determination of the proper lamp voltages in any central-station system is a matter demanding the most careful investigation and consideration. Concrete examples showing the losses attendant upon operating lamps at improper voltages are given. An appendix gives tables and data for 25-watt, 40-watt and 60-watt tungsten-filament lamps and for 60-watt metallized-carbon-filament lamps, also tables summarizing the conditions found in the eighty-two central-station systems visited and inspected. 338 to 367

Cooper, M. D. See Campbell, R. E.

Doherty, H. L. *Address:* The history of the Power Transmission Section is briefly sketched, beginning with its organization at St. Louis in 1910. Over thirty million horse-power lie undeveloped along American streams and rivers. Much of this is far distant from a market and requires cheap transmission for its profitable utilization. There are numerous electrochemical processes which need cheap power more than advantageous geographical location. There is much arid land which is too high to be irrigated by gravity systems, and can only be made productive by sinking wells and drawing upon the ground water with electrically driven pumps. Farm uses for electrical energy are also important and need stimulation. There is a need for developing cheap forms of high-tension line construction to operate at the highest possible voltage. The conservation policy of the United States Government is obstructive to the development of water-powers and is seriously impeding progress. It is a mistake to assume that the forests are so essential in conserving stream flow and as a matter of fact tilled soil is fully as effective as forest growth. The present conservation policy seems to be responsible for sending large numbers of our western farmers to Canada. Such a policy of government is in marked contrast with that which now exists in Germany, where citizens are tending more to stay at home because of the new opportunities which have been created there under progressive government policies. The tendency toward muckraking of American business methods and business men is deplored. 2 to 8

Elden, L. L., Chairman. *Report of the Committee on Electrical Apparatus:* The body of the report is very brief, the principal details being presented in a voluminous illustrated appendix. The demand for better steam turbine economy has resulted in the use of higher speeds. Increased recognition is being given to the great economic advantages of generating energy in very large stations, and distributing it by means of extensive interconnected networks. There is a demand for simpler and more rugged switchboard equipment in substations. The use of iron-clad switch gear is being favorably considered in this country, and the committee recommends that it receive careful attention. Illustrated.

Discussion by Ryerson, Yawger, Hayes, Stone. 549 to 610

Faccioli, G. *Corona on High-Tension Lines:* It is pointed out with regard to the occurrence of this phenomenon that while not necessarily dangerous, it is unsafe to permit its occurrence to any great extent. One of the possible dangers is the production of ozone, nitrogen oxides and nitrous or nitric acid, which may attack the insulating and conducting materials The law of corona is presented in considerable detail. The paper concludes with a description of the 140,000-volt, 125-mile transmission system in Michigan operated by the Au Sable Electric Company, with particular reference to the operating characteristics and the occurrence of corona. Illustrated.

Discussion by Bowie, Nims, Rushmore, Hayes, Kerr, Cheney, Stone. 207 to 237

Gardiner, W. H., Chairman. *Report of the Committee on Terminolgy:* The report is confined to the definition of terms pertaining exclusively to central-station business. Certain terms and definitions relating to accounting were left to the Committee on Uniform Accounting, but definitions adopted by the Rate Research Committee were included in the report. Among the terms defined are "capacity," "demand," "load factor" and "diversity factor." The term "watt-hour meter," as

applied to an instrument registering watt-hours, is recommended in place of the incorrect terms "integrating wattmeter" or "recording wattmeter," now often employed. The definitions presented by the Rate Research Committee cover such terms as "flat rate," "demand rate," "meter rate," "two-charge rate," and similar terms.

Discussion by Peart. 369 to 376

HAYES, S. Q. *Switchboard Practise for High-Tension Power Transmission:* The author describes not only the panel, pedestal and bench types of switchboard, but also other features of generating station and substation apparatus, as well as some of the general features of station design. The paper includes illustrations of the following installations: Tacoma municipal plant, Mount Hood Power Company, Olympic Power Company, Winnipeg municipal plant and the Hydro-Electric Power Commission of Ontario. Illustrated.

Discussion by Bowie, McGee, Rushmore, Peart. 160 to 192

HOYT, J. C. *Work and Publications of the United States Government Relating to Hydro-Electric Development:* This paper describes the work carried on by the United States Government in collecting and disseminating technical and engineering data. The paper refers particularly to such information as is required in reporting upon the feasibility of hydro-electric power developments. Government data relating to this subject can be grouped under the following six topics: Water-power, topography, geology, climate, social and industrial conditions, and experimental engineering data. The work of the various bureaus and departments is reviewed and the paper concludes with an explanation of the procedure which should be followed in obtaining Government reports and documents. Those who desire to keep in touch with all the information of this character as it appears, should subscribe for the Monthly Catalogue of United States Public Documents, issued by the Superintendent of Documents, at Washington, D. C.

Discussion by Jacobs, Britton, Doherty, Ryerson, Parker. 80 to 97

JEWETT, F. N. *New Current-Consuming Devices:* The paper deals with single-phase converters and rectifiers adapted to charging electric vehicle batteries, and for miscellaneous other uses, such as moving picture and theatrical work, operating telegraph systems and railway signals. This class of device is limited to a capacity of 5 kilowatts or less. The apparatus has been developed by one of the well-known manufacturers. The single-phase synchronous converter resembles, in its outward appearance, the single-phase commutator type of motors built by the same manufacturer. It may be started with equal facility from the alternating-current or the direct-current side. Voltage regulation is facilitated by means of a special transformer on the alternating-current side. For charging very small storage batteries, such as those employed for automobile and motor-boat ignition and lighting, the manufacturer has developed a single-phase mechanical rectifier. Illustrated.

Discussion by Lighthipe, Osgood, Naylor, Wilson. 377 to 390

KENNELLY, A. E., Chairman. *Report of the Committee on Electrical Measurements and Values:* The report reviews the recent official minor changes in the units of candle-power and voltage. On July 1, 1909, the Bureau of Standards, with the consent of the American Institute of Electrical Engineers, the National Electric Light Association, the Illuminating Engineering Society and the American Gas Institute, lowered the value of the unit of candle-power by 1.6 per cent, thus establishing uniformity with the standard adopted by Great

Britain and France. This lowering of the unit resulted in a general increase in candle-power ratings, or if the candle-power ratings remained the same the voltages were slightly reduced. The general effect of this change has been to diminish by 1.6 per cent the amount of light furnished by lamps manufactured since the new standard became effective. At the same time the serviceable life, which expires when the candle-power falls to 80 per cent of its initial value, was increased to 7 per cent. On Jan. 1, 1911, the Bureau of Standards, under international agreement, introduced a slight change in the value of the standard volt. The electromotive force of the standard Weston cell was changed from 1.01913 volts at 20 degrees C. to 1.01830 volts at 20 degrees C., a reduction of 0.08 per cent. Automatically the standard ampere became larger to the extent of 0.08 per cent, and the watt by 0.16 per cent. While these two changes tended to offset each other, the effect of the change in the candle-power unit was the greater of the two. The changes went into effect at the Electrical Testing Laboratories in New York without serious inconvenience.

Discussion by Sharp. 330 to 337

McConahey, W. M. *Care and Operation of Transformers:* The paper deals mainly with oil-insulated transformers, but refers briefly to the air-blast type. The two primary essentials in transformer design are insulation and heating. Perhaps the most important matter in connection with oil-insulated transformers is the matter of keeping the oil in proper condition. Moisture in the oil is the most insidious fault which can occur and should be carefully guarded against. Self-cooling transformers are at present being built in sizes up to about 3000 kilowatts. Larger sizes than these have to be water-cooled. Large transformers should be periodically inspected about once in six months, at which time the oil should be tested, and the cooling coils should be examined to determine whether they have accumulated deposits from the oil or scale from the water. Air-blast transformers form a class by themselves and their use is comparatively limited. Transformers of this type will quickly reach a dangerous temperature if the air blast is shut off while carrying full load. When two or more transformers are to be operated in parallel or connected in banks on a polyphase system, it is necessary to know their polarity in order to connect them properly. The author devotes the latter half of his paper to a consideration of the numerous polarity combinations in polyphase banks, making extended use of potential diagrams. Illustrated. 657 to 688

McKee, J. R., Chairman. *Report of the Committee on Power Transmission:* Owing to the character of the committee membership it was very difficult to hold meetings during the year. The committee reports that it is unanimously of the opinion that water-power franchises should run for an indeterminate time, a position which was concurred in by the American Institute of Electrical Engineers. Members of the committee gave some attention to legislation and appeared before committees of Congress to give testimony in reference to the best policy to be followed in develpoing water-power sites. The withdrawal of Government lands is declared to have stifled development in the west. The reaction has stimulated hydroelectric development in the south. The Niagara Falls situation is discussed, and it is pointed out that the use of 20,000 cubic feet per second more of water would detract in no detectable degree from the scenic grandeur of the Falls and would add 500,000 horse-power to the utilized supply. The report declares that if we were to waste our coal deposits as rapidly as we are allowing our water-powers to

run to waste there would instantly be loud protest from the public. Reference is made to Senate bills introduced by Senator Burton and providing for the development of water-power sites on the public domains. These bills are not satisfactory. The present restrictions on the development of water-power sites withdrawn from entry are declared to be extremely burdensome, and it is pointed out that the supreme need of the moment is education of the public on these questions.

Discussion by Doherty, Rushmore. 98 to 109, 120

MARTIN, T. C., Chairman. *Report of the Committee on Progress:* This is part two of the report on progress and covers the subject of power transmission under the following ten topics: Legislation, sources of power, international exchange of energy, Wisconsin water-power law, private purchase of municipal energy, combined steam and hydro plants, use of aluminum conductors, some new hydro-electric systems, plants operating at high voltage, some coming power transmission plants. 123 to 159

MILTON, TALIAFERRO. *Twenty-four-Hour Service in Small Central Stations:* The author discusses the possibilities resulting from the use of storage batteries. Such use is considered under three heads: First, in new plants where a sufficient number of profitable customers cannot be obtained without giving a 24-hour service, which would be prohibitive if it were necessary to operate the generating plant continuously; second, in existing plants where the inauguration of a 24-hour service would secure additional customers and yearly revenue; third, in plants like the last where the inauguration of a 24-hour service would so improve the quality of service that the increased returns would more than offset the charges on the additional investment before the elapse of a considerable period. A number of examples are cited where storage batteries have been successfully employed in small direct-current plants. Among those mentioned are the New Windsor Electric Light and Water Company, New Windsor, Md.; the Jordan Electric Light Company, Jordan, Minn.; the Chester Electric Light Company, Chester, Mass., and others.

Discussion by Crane, Murphy, Atkin, Naylor, Osgood, Lighthipe, Korst, Jewett. 391 to 402

MOULTROP, I. E., Chairman. *Report of the Committee on Prime Movers:* In connection with water-power the following subjects were discussed: Turbines, governors, relief valves, stand-pipes, penstocks, water measurement, storage reservations, auxiliary steam plants and ice troubles. In discussing steam-power the committee took up the following subjects: Coal purchase, large-size boilers, mechanical stokers, steam-flow meters, feed-water regulators, pitting of feed-water piping, fatigue of cast-iron in connection with superheated steam surface combustion boilers, high-efficiency reciprocating engines, steam turbine developments, condenser performance, and improvements in reduction gear for steam turbines. Under the subject of gas power the committee presents statistics of fuel-oil production and discusses the subject of specifications for engine fuel oil. Special attention is given to the experience reports from users of various types of oil engines, embracing a total of 38 installations. Oil and gas producers are discussed and the Humphrey gas pump is described in detail. Mention is made of the possibility of utilizing waste heat from internal combustion engines. Brief mention is also made of the gas turbine and the alcohol engine. Illustrated.

Discussion by Denman, Junkersfeld, Stone, Harding, Kemper, DeWolf, Yawger, Lighthipe, Egan, Wallis, Pratt, Harrington, Foran, Klumpp 467 to 548

Osgood, Farley, Chairman. *Report of the Committee on Overhead Line Construction:* The committee did not prepare a formal report in advance, for the 1912 convention. The elaborate report presented at the 1911 convention was formally approved by the Executive Committee for the Association, last December. It was adopted verbatim by the Association of Railway Telegraph Superintendents. It was also taken up by the American Electric Railway Association, approved by the technical session, and recommended to its standards committee. When the report was taken under consideration by the American Railway Engineering Association, there was a desire to make numerous changes. At last a compromise was reached, resulting in the proposal to change only some of the provisions of Section 18, relating to strain insulators in guys. In the opinion of the chairman, the Association could well afford to accept the compromise proposed by the Railway Engineering Association. He offered a resolution to that effect, the motion was put to vote, and unanimously carried. Illustrated.

Discussion by Wilson, Lighthipe, Goodwin. 403 to 465

Paine, F. B. H., Chairman. *Report of the Committee on Receiving Apparatus for Use on Transmission Lines:* The committee submits the following suggestions: The most important thing is not to cut out equipment until it is necessary or until the disturbance is shown to be more than momentary. Inverse time-limit relays should not be permitted. When maximum continuity of service is the first essential it is preferable to employ induction motors instead of those of the synchronous type. Where the use of synchronous apparatus is unavoidable it is desirable to provide separately driven exciters or a separate source of supply for the field excitation. No doubt exists as to the benefit derived from the use of heavy copper dampers on the pole faces of synchronous machines. The committee particularly recommends the development of apparatus for keeping a continuous record of system disturbances in order to know their actual time of occurrence and their duration, with the object of afterward carrying on such investigation as may be necessary to remove the causes. Illustrated.

Discussion by Rushmore, McGee, Lighthipe, Williams, Hanscom, Bragg, Ryerson, Bowden, Peart. 194 to 206

Sprong, S. D. *Meter Installations:* This paper takes up the commercial aspects of the problem, with special reference to small customers. The author presents a table showing the distribution of 35,000 meters of different sizes. Five-ampere meters make up 58.8 per cent of the whole, and meters with a rating ranging from 10 ampere to 25 ampere amount to 14.3 per cent. Considering particularly the small meters, which compose about three-fourths of the total, the author states that the average cost of the meter is $15 and the average cost of installation is $13, making the total investment $28. The corresponding annual charges are $3.40. One of the problems now demanding the most serious attention is the development of cheaper metering devices for the small consumers. Among the principal considerations are the prevention of tampering with the apparatus and the theft of energy. The author points out that with the advent of lamps of still higher efficiency it may become economical in the smaller installations to serve the customer on a flat charge per lamp basis. Illustrated.

Discussion by Rhodes, Wallace, Bushnell, Junkersfeld, Jenkinson, Henkle, Vaughan, Stacy Hamilton. 286 to 307

Sprong, S. D., Chairman. *Report of the Committee on Protection from Lightning:* The report is devoted almost entirely to a consideration of the best means of carrying on the work which falls within the

committee's scope. In view of the knowledge and data thus far gained of lightning phenomena, it is felt that further work along established lines could yield little additional material of substantial value. At the same time it is very important to carry on investigations looking toward the solution of a number of important problems, but these investigations require the trained observation of experts and should be facilitated by the development of special apparatus for automatically making a continuous record of lightning disturbances. The committee recommends that it be given an appropriation to carry on experimental investigations in representative systems along the lines suggested.

Discussion by Rushmore, Gear. 238 to 244

SMITH, F. W., Chairman. *Report of the Lamp Committee:* The report opens with a résumé of the three previous reports for 1909-1911. Statistics on lamp sales show that in 1911 the total sales of domestic lamps of all standard types were about 85,000,000, an increase of 8.45 per cent over the previous year. A table is presented showing the distribution of total sales among carbon, graphitized, tantalum and tungsten types. The percentage of carbon lamps has been steadily decreasing and in 1911 amounted to 52.9 per cent of the whole. Indications point to a further decrease in the output of the lamp, and in 1912 the sales may not exceed 20 per cent. The committee recommends that all member companies, large and small, adopt the graphitized filament lamp as a substitute for the carbon lamp. Development during the year has resulted in adding substantial mechanical strength to both the drawn-wire and the wire-type tungsten filament. In consequence of the improvements it has been possible to standardize the useful life at improved efficiencies. New tables of life, specific power consumption and candle-power are presented. The committee reports that the use of special tungsten sign lamps has resulted in a considerable stimulus to the electric sign business throughout the country. The new types and sizes of lamps announced by the manufacturers since May 1, 1911, are presented in tabular form. The lamp manufacturers have announced an entirely new selling plan, intended to meet the decree of the United States Circuit Court entered on Oct. 12, 1911. The member companies are urged to follow a broad and liberal policy in encouraging the adoption and use of the tungsten lamp.

Discussion by Lieb, Howell. 314 to 329

WILLIAMS, C. H. *Use of Electricity for Irrigation and on the Farm:* The greater part of this paper is devoted to a description of conditions in the large irrigation districts east of the Rocky Mountains. The earliest method of irrigation was by means of gravity ditches. This was soon supplemented by low-head pumping, in order to reach contours above the ditch levels. Owing to excessive losses through evaporation and seepage, attempts have been made to obtain water supplies from driven wells. The last method seems to be the most satisfactory of the three. Costs of well drilling and pumping are given. Motor-driven centrifugal pumps are used almost exclusively. A brief description is given of the steam generating station operated by the Northern Colorado Power Company for supplying irrigation districts embracing over 3000 square miles. Energy is transmitted at 44,000 volts, and distributed at 6600 and 2300 volts. Motor applications on the farm for grinding and mixing feed, cutting ensilage, operating vacuum cattle cleaners, driving vacuum milking machines, small refrigeration plants, cream separators, butter churns, etc., are briefly described. Illustrated.

Discussion by Wallau, Pen Dell, Britton, Insull, Davidson, Doherty, McGee, Junkersfeld, Hays, Kingman, Ballard, Wells, Hahn.

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E. J. Bowers, Chairman

E. J. Allegaert — C. E. Bowden — J. H. Gulick
J. L. Bailey — C. N. Duffy — H. R. Lyons
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TECHNICAL

Technical

W. F. Wells, General Chairman

Prime Movers

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W. H. Blood, Jr., Chairman

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Protection from Lightning and Other Static Disturbances

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John W. Lieb, Jr., Chairman

Louis Bell
Alex. Dow
C. P. Steinmetz
R. F. Schuchardt

Power Transmission Sessions

POWER TRANSMISSION SESSIONS

FIRST POWER TRANSMISSION SESSION—JUNE 11, 8.30 P. M.

1—Address of Chairman. H. L. DOHERTY.

2—Report: The Uses of Electricity for Irrigation and Agricultural Purposes. C. H. WILLIAMS.

SECOND POWER TRANSMISSION SESSION—JUNE 12, 2.30 P. M.

1—Paper: Work and Publications of the United States Government Relating to Hydro-Electric Development. J. C. HOYT.

2—Report of the Power Transmission Committee of the Association. J. R. McKEE.

3—Report of Committee on Power Transmission Progress. T. C. MARTIN.

4—Paper: Switchboard Practise for High-Tension Power Transmission. STEPHEN Q. HAYES.

THIRD POWER TRANSMISSION SESSION—JUNE 13, 2.30 P. M.

1—Report of Committee on Receiving Apparatus for Use on Transmission Lines. F. B. H. PAINE.

2—Paper: Corona on High-Tension Lines. G. FACCIOL.

3—Report of Committee on Protection from Lightning and Other Static Disturbances. S. D. SPRONG.

FIRST POWER TRANSMISSION SESSION

TUESDAY EVENING, JUNE 11

THE CHAIRMAN (MR. HENRY L. DOHERTY), New York City: Gentlemen, the second annual convention of the Power Transmission Section of the National Electric Light Association will come to order. The first thing on the program is the reading of the Chairman's address, and I will ask Mr. Blood to take the Chair.

OPENING ADDRESS OF HENRY L. DOHERTY, CHAIRMAN, POWER TRANSMISSION SECTION, NATIONAL ELECTRIC LIGHT ASSOCIATION

The Power Transmission Section was organized at the St. Louis Convention in 1910.

Its purpose is to organize the men skilled in or otherwise interested in the construction and operation of hydro-electric plants, and also in power transmission by means of electricity, no matter how such electricity may be generated.

There has been heretofore no common association or society where the men essential to this work could meet, exchange views and co-operate. There are many people of varied professions and occupations interested in these subjects, for instance: The hydraulic, the civil, the mechanical and the electric engineer, the capitalist who furnishes the money, the banking and bond house that sells the securities, the power user, etc., etc.

The detail of organization has proceeded slowly but substantially. The men interested in this work are widely scattered and time will be required to bring about their amalgamation. An example of the growth which may be anticipated is furnished by the Commercial Section. In 1902 we endeavored to have one day devoted to commercial work at our convention in Cincinnati, Ohio, but were either unable to find men interested in the work or to enlist their support. In 1904 we first gave a portion of our time to commercial work, and this work grew constantly in volume and importance until in St. Louis, in 1910, the Commercial Section was organized which now has 1325 members and is doing work of greater importance and scope than would be indicated by this volume of membership. It remains to be seen whether the original members of this section have enough of the commercial spirit to reach, awaken and secure the co-operation of the vast number of men interested in power problems.

A more descriptive name for this section would have been the Hydro-electric and Power Transmission Section. Its work if properly done will have a vast bearing on the progress and

prosperity of the entire country. There still remains in this country over thirty million horse-power of undeveloped water-power, which alone represents an enormous reservoir of latent wealth slowly being brought into use, but by the work of this section the realization of this wealth can be greatly accelerated. Much of this power lies far distant from any existing market, but the essential factors for creating a market are oftentimes near at hand, and if this section should devote itself merely to the problem of how this power can be transmitted to existing markets (important as this is) it would fail to realize its full opportunity.

There are numerous electro-chemical processes that require primarily cheap power rather than advantageous geographical location, and it is only necessary to transmit this power to some reasonably economical transportation system. Much of this undeveloped power lies within transmission distance of water transportation and with cheap power delivered at tidewater the markets of much of the whole world are available. As another example, there is much arid and semi-arid land which lies at too high an elevation to be irrigated by gravity, and yet an abundance of water can be taken from wells or nearby streams and an abundance of hydraulic power for pumping can be secured within a distance which is readily available for transmission by means of electricity. Many of these creative markets do not demand absolutely uninterrupted service, thus permitting the use of single transmission circuits of the cheapest possible construction and the use of the highest voltages. We are already transmitting electrical energy for distances to exceed 200 miles, and in some instances using voltage as high as 140,000, and both voltage and mileage pertain to service which must be of the highest type of reliability.

It is not the province of this address to go into specific details of work to be done by the section, and I cite the above simply as examples to encourage an effort to utilize our distantly located water-powers. Probably within the coming year a competent committee will be put to work to outline all of the present possibilities of these distant powers. The very fact that some of these uses do not demand complete freedom from interruption will enable us to do the necessary pioneer work to carry us to greater voltages and greater distances.

Aside from the problem of bringing our hydro-electric power to a market or the creating of a market for it, we have numerous problems to solve in the transmission and distribution of electrical energy, whether it be generated by fuel or water. Chief among these is the problem of how to get energy to the farm. The application of electrical energy has been so rapid that our efforts have heretofore been directed almost exclusively to serving the districts having the greatest density of consumption. We are now ready to attack the problem of how to reach all possible markets. Several central stations are pioneering in the application of electricity to the farm, and some excellent work has been done by our fellow members in the Commercial Section. The "Report of the Committee on Electricity in Rural Districts," presented to the Commercial Section at this convention, and a similar report of last year, deserve the attention of all our members. Unfortunately the time available at our conventions necessitates the use of parallel meetings and the work of the sections is bound to overlap somewhat. There is no jealousy, fortunately, in the National Electric Light Association. We applaud the enterprise and progress of the Commercial Section in the excellent work they have already done to bring about the extended use of electricity on the farm, and we promise them our support in solving the technical and engineering problems.

Farming, when carried to its ultimate possibilities, requires excellent judgment, good managerial ability and perhaps a greater amount of scientific and professional skill than any of our other professions, but unfortunately, as now conducted, it also demands the hardest kind of manual labor. Plowing must be done when fleeting conditions are propitious and crops must be gathered when they are ripe, and neither at the convenience of the farmer. Applying an electrical term to farming, we might say that farming has a very bad load-factor. Electricity on the farm will largely displace manual labor and make this occupation more a contest of professional skill than of bodily strength and endurance, and especially in the South, where nature's conditions favor the growth of crops to the impairment of man's ability to labor. In extending the use of electricity on the farm we are confronted with new and difficult conditions. The density of consumption is so light that prevailing methods of transmission and distribution are inadequate. We must look to our com-

mercial department primarily to secure the application of all known uses, and to the engineering fraternity at large to develop the means of distribution and the creation of the appliances that are to supersede manual labor. We must also enlist the support of the scientific farmer in finding new uses for electricity in agriculture as a means of increasing the density of demand, thus bringing about greater sales of energy to support the investment cost of building the necessary transmission lines. Even in sections generally supposed to have abundant rain irrigation by means of electric pumping can be made profitable. It has also been found that the growth of crops can be greatly stimulated by the use of a suspended network of wires upon which is forced a high electrical pressure. With the advent of our new high-efficiency lamps even in the smaller units and the greater use of the automobile it is not unreasonable to expect the adoption of lighting systems for our country roads. This will do much to aid in bringing about the supply of electricity to the farm.

It is rather interesting to note that the greatest obstacle to the development of the millions of horse-power of hydraulic energy still unused is the United States Government. Under the guise of the conservation of our natural resources a remarkable school of political economy and statesmanship has sprung up. It would be humorous were it not so serious. We are told that we must conserve our natural resources for the sake of posterity, and we have been saddled with an alleged plan of conservation which has brought about most flagrant and inexcusable waste, which has stagnated development and prosperity in our great western country and has turned the stream of pioneer settlers toward Canada.

For many years the conservative statesmen of this country have regarded the public lands as a public trust to be used for the development of the section in which they are situated, but the new school of alleged statesmen, after inaugurating a campaign of misrepresentation and hysteria, have construed the ownership of the public lands to be theoretically for the enrichment of the Federal treasury, although in practise millions of dollars have been spent or wasted in applying the mistaken theories of impractical men. Areas more than one hundred times greater than some of our smaller eastern States have been

withdrawn from entry since this conservation policy has been ushered in. Millions of tons of coal have been mined and burned to furnish power that might have been generated by water now running idly to the sea. Millions of acres have been withdrawn from entry and much reserved for National forests primarily on the theory that this policy conserves the flow of the streams. It is certainly not proved that the forests do conserve the flow of the streams, and it is a matter capable of easy proof that forests do not conserve the flow of the streams as well as the tilled soil does.

The public lands instead of being assets to the States in which they are situated have become a great obstacle to their growth and development. Great railroads cannot be operated successfully when large stretches of unproductive, uninhabited lands must be passed. Natural development is thus discouraged and retarded. Large numbers of our desirable western farmers are migrating to Canada. Water-powers that might be constructed and which would bring about new industries are lying idle and it is not to be wondered at that many intelligent people express contempt for conservation when in reality they intend only to fight this false conservation that has been thrust upon them by an impractical school of fanatics and theorists.

The opposition of the Government has spread to other Bureaus and it is now almost equally difficult to get permission to make a water-power development on the navigable streams, even although many of these streams are navigable only by chips and small logs. Permission is now being sought for a reservoir on one of these navigable streams, which is in fact non-navigable, and in addition to the other burdens which the Government wants to impose, the Secretary of War insists that the builders shall pay such rental for the site as the Secretary of War may fix from time to time, and in addition to this the Secretary of War shall have the right from time to time to regulate the rates charged to consumers. This particular reservoir will be a small portion of a large steam generating and distributing system, serving over 200 square miles of territory in two different States. Imagine the Secretary of War adding to his legitimate duties the regulation of electric rates, and the poor electric company submitting not only to the inherent regulation of rates which each State undertakes for its public service corporations, but to those of the Secretary of War as well.

We are passing through a period when the builders of the great enterprises of the country are regarded as public enemies. Building operations have been carried on for the past five years at less than normal rate and a continuation of this condition must inevitably bring the whole country to a low ebb of prosperity.

I cannot but contrast the policy of the administration of this country with that of Germany. History will paint the German Emperor not as what we see him caricatured to-day, but as the man who retrieved German commerce and industry. The enormous German immigration which helped for many years to populate this country has almost ceased, and only recently I was told by the publisher of a large German newspaper that the day is fast approaching when there will be no call for a paper such as his, published in the German language. In Germany if a man builds up a great enterprise they decorate him, but in this country we try to send him to jail. The German policy has told its story in the wonderful prosperity which an apparently disintegrating country has attained in a few years and our policy if continued will in time tell the opposite story.

The policy of our government is simply another symptom of a widespread hysteria. The people believe there is something wrong and stand ready to follow any unscrupulous demagogue or impractical dreamer who promises to correct these wrongs, and, as in our conservation movement, practically everything that is done accentuates the wrongs of which they complain rather than corrects them. In spite of the statements of our new school of alleged statesmen and our muck-raking publications, the American business man is the most honest and reliable of his class in any country, and this statement is borne out almost universally by foreign business men who do an international business. His reputation is maintained in spite of the army of muck-rakers, who never fail to accord a gratuitous insult to the American business man whenever opportunity affords, to the great delight of our many foreign enemies. I wish we could quit fighting symptoms and devote our time to the underlying disease. The public has come to believe that there is something radically wrong in our business methods and seems to be willing to follow any man, no matter how incompetent he may be, provided he is sufficiently intemperate in speech. If wrongs exist they should be corrected, and if these wrongs are imaginary they

should be explained away. The business men of the country should inaugurate a new move, if not for their own protection, then to free our people from incompetent leadership which can bring only harm to us as a nation.

(Mr. Doherty resumed the Chair.)

THE CHAIRMAN: We will now have Mr. C. H. Williams' paper on electricity in irrigation and agriculture, and this will be the only paper for the evening. What we want is to have time for discussion or the asking of questions on what is presented either orally or on the screen. Mr. Williams is not able to be here, but he has sent his assistant, Mr. Hahn, who will present the paper.

MR. HAHN, Denver, Colo.: When Mr. Williams prepared his report he felt that the subject was a little too broad and uninteresting for the average convention attendant. After he finished it he said it was too long to be read and thought that a delegation of western farmers would be more interested in it than the section. In order to overcome both objections he decided to present the subject by means of motion pictures and slides. Mr. Williams took the pictures, developed them and printed them himself, and as these are the very first pictures he ever took, he wishes me to make his apologies for what is amateurish in them.

USE OF ELECTRICITY FOR IRRIGATION AND ON THE FARM

The application of electric power for irrigation pumping requires a knowledge of irrigation engineering, and as irrigation engineering is a product of the present generation, a discussion of electric pumping will be more comprehensive when prefaced by a few statements concerning irrigation work in general.

Two kinds of irrigation are in use: The ordinary gravity flow, such as that of taking water from a reservoir and ditch, and the mechanical lift, such as pumping water from a well, and of the two, the development of the mechanical lift is far more rapid.

In any country where the annual precipitation averages less than twenty inches, agriculture cannot be carried on successfully without resorting to some means of supplying water artificially to the land.

There are three hundred million acres of such lands lying immediately east of the Rocky Mountains and between the limits of Canada and Mexico, and these lands present one of the greatest problems ever found in the development of agriculture. The area is tremendous, the soil is deep and fertile, the climate is healthful and agreeable and all conditions are ideal, except for the lack of moisture. Of this territory, the States of Colorado and Wyoming occupy the richest part. For a distance of one hundred miles from the mountains toward the east, the precipitation will average but fourteen inches, while in the mountains it is greater. Winds heavy with moisture are brought in contact with the colder mountain peaks and precipitate it largely in the form of snow.

However, Nature has provided that this limited amount of precipitation is so distributed that it does the greatest amount of good. Accurate reports on the Cache La Poudre River basin, a representative irrigation stream in Colorado, show that 55 per cent of all the rainfall on the plains falls during the growing season. In the mountains, where practically all of the irrigation rivers have their source, the conditions are reversed, and the greater portion falls between October 1 and the last of April. These winter snows lie as storage in the mountains until melted

Virgin Soil

Dry Farm Across the Road From Virgin Soil

PICAL IRRIGATION SCENE—SAGE BRUSH IN FOREGROUND, ROCKY MOUNTAINS IN DISTANCE

IRRIGATED FARM ADJOINING DRY FARM

late in the summer and then run down and supplement the rainfall on the plains when water is most needed. The importance of this to irrigation is apparent from the statement that 82.5 per cent of all the precipitation on this watershed is available on the plains, either as rainfall or as stream flow, during the short growing season between the first of May and the last of September.

Early Developments

Some of the first irrigation developments in Colorado were undertaken on this Cache La Poudre River. The first work was done by the gravity system and the easiest means were used to divert water from the natural streams. Lands were plentiful and so was the water in the streams, and the valley lands which could be covered with the least expenditure were put under ditches first. It was found easier to carry water farther down the stream and to supply other valley lands than to try to follow the contours of the uplands, or to build ditches across ravines, or draws, and so the uplands, which were often better lands for agricultural needs, were left for later settlers to find a means to water.

The gravity system was the only one considered at that time, and at present when an abundant supply of water is available from a stream, the cost of building low, the losses not excessive, and where the land permits of the easy grading of ditches, the gravity system has an advantage over pumping, but the reverse is true in many cases. Even where a gravity system is employed, pumping is recognized as a most valuable adjunct, as there are conditions under which no other means of securing water is available, as in every irrigated district lands are found which lie above the contour of the ditch—fine table lands of rich fertility, but valueless for agricultural work without some means of getting water to them.

There are conditions under which the gravity system is practically impossible, and oftentimes the losses which occur are such as would ruin any other kind of enterprise. Where ditches are built by excavating in loose soil, or by throwing the dirt upon the sides to make embankments, the losses are enormous, and when the ditch is new it is often difficult to admit sufficient water at the headgate to obtain a run at the lower end.

The Government engineers have made careful observation on many ditches of this kind and find that the losses vary from a small amount up to 25 per cent per lineal mile of ditch, with an average of 5½ per cent per mile. The losses in older ditches are reduced by the silt which is deposited by the water and which fills the openings in the sides and bottoms, and to assist this action, clay is sometimes added to the water where it is easily available, to increase these deposits, where the flow of water is sufficiently slow to allow the deposit to take place. Sheep are sometimes driven through a ditch and the continued pounding of their feet is quite effective in closing up the openings. Many gravity systems show that for every acre-foot of water put upon the land, four feet have been diverted at the headgates and many specific instances bear out these statements.

Losses in Ditches

Last year test measurements were made on the Water Supply and Storage Company's ditch, known as the Pierce Lateral, located in Weld County, Colorado. This ditch had been carrying water for three years when the tests were made, and to determine the losses, the water was measured at the headgate and again at a point fifteen miles down the ditch. A comparison of these measurements showed that one-half of all the water admitted at the headgate was lost through seepage by the time the fifteen miles had been traversed; and this was not all, as the losses continued to occur as the water passed through the laterals into the individual ditches and out through the farm ditches, and it would be easy to see how the final quantity of water run upon the farms could be reduced to but a quarter of the original amount diverted from the river. These losses were not measured on the earlier developments and their amount is not fully appreciated by the majority of the water-users now.

Decrees on Water Rights

When irrigation developments first started, the Legislatures had failed to make appropriate provisions to regulate the manner of perfecting rights or titles to the water, and when cases were referred to Courts, the Courts were at a loss for precedent on which to base their rulings, and as the results of their decisions were oftentimes conflicting, the claimants were not always greatly benefited by appealing to the Courts.

This condition became so critical that the Agricultural Department undertook to straighten matters out, and in studying Court decrees they found that practically no relationship existed between the appropriations on a stream and the actual amount of water which was there available, and practically no relationship existed between the capacity of canals which had been built and the volumes of water which were put to beneficial use. A man appropriated water from a stream and was granted without question the largest amount he ever claimed to use. He used the water only periodically, and so another man might have an equal appropriation with a different time of use and as long as the demands of several appropriators were not coincident, no difficulty was experienced.

The rights to water had a money value, and the first appropriator either secured greater acreage to irrigate, or disposed of portions of his rights to others, and by these actions increased demands were made upon the ditch. Every man who had appropriated water believed himself entitled to the amount of his appropriation, whenever he should choose to use it, although his demands were only intermittent at the start. The next appropriator considered himself to be in like position, although he recognized that his use could not impair the rights of the first appropriator. As additional lands were irrigated, demands increased and the use of water became more uniform and continuous, and soon demands outgrew supply. A condition is frequently found to-day where there are streams on which the filings exceed many times the total flow, and when the holders of these water-rights attempt to use them, disappointment must result to many who think their rights are good.

A large acreage is added to irrigated lands each year and a condition has been reached where the price of water will go up, not down, and Dr. Fortier says that we shall never again see the day when water will sell for less than it did last year.

This condition needs a remedy, a remedy by which a greater duty will be realized from the water supply at hand, or by which an added supply will be made available.

In this connection, it is of interest to inquire what becomes of the water run upon a field?

The greater portion sinks down through the soil and apparently is lost by gravity.

Pumping From a Ditch to Land Above the Ditch

Covering 320 Acres From a Sump

Another tremendous loss is from evaporation, and on a hot, dry, windy day this loss will equal or exceed the amount of water which the growing plants absorb. A measure of this loss may be of interest. At the Northern Colorado Power Company's power plant, there is a reservoir holding 26,000,000 cubic feet of water; in one year, evaporation alone lowered the surface of this reservoir seventy-eight inches, or six and one-half feet, and as the rough surface of a field offers practically three times the surface contact for the air to act upon, where the air gets in around and under each particle of dirt upon the surface, the loss would be much greater on a field than on the reservoir on which the measurements were made.

In order to cut down this action on a field, water is carried in deep furrows and with careful handling the losses are reduced one-half. When the surface is allowed to bake and harden the losses are increased, and careful irrigators can further reduce this waste by breaking up the surfaces by cultivation, after irrigation is completed. This cultivation leaves a dry mulch of earth upon the surface, which acts as a blanket to the under soil. The time of day at which the water is applied is also an important factor. During the midday, when the sun is bright, the temperature of the air is high, that of the ground relatively low, the differential great, the losses are in direct proportion. On the Colorado plains the wind blows in the daytime and each successive layer of dry air takes up its fill of moisture as it passes over. At night, the temperature of the air and ground is nearly equal, the humidity of the air is high, and a layer of air in contact with the ground may reach its saturation point but is less likely to be displaced by other air, and for this reason, if water is applied at night, the losses are materially decreased.

All this explanation has been made to prominently point out the fact that the actual amount of water put to beneficial use upon the farm is but a fraction of the quantity diverted from the stream, an important fact which is referred to later on when considering the possibility of increasing the duty of the waters now made use of.

Underflow

Other waters are available than those found in the surface streams. Engineers' reports show that only one-half of the precipitation in the hills is accounted for in stream flow, and it

is a natural question to ask what becomes of the vast quantity unaccounted for. This seeps into the ground, finds passage below the surface soil and gradually travels eastward and may appear as springs along the Mississippi Valley. Below the surface of the plains are strata formed of different materials, such as sand, gravel, clay, shale and rock, through which the water passes at velocities dependent on the compactness of the beds. In loose sand and gravel, the water finds a freer passage than in clay or rocks, and large quantities are available where these strata can be found and intercepted.

The waters which pass down the streams and are diverted through the ditches or into reservoirs and then through ditches to the fields, add further quantities through seepage losses, to increase the underground supply.

This seepage action is pronounced and the system of irrigation in the arid West has raised the water table by a gradual increase of this ground supply, and in Colorado has amounted to a rise of from 20 to 40 feet, and even more in places where irrigation has been carried on extensively.

A practical demonstration of the fact was shown by the action of a 28-ft. irrigation well put down some years ago near Greeley, where the first colony of white men settled in Colorado in 1870 on the Cache La Poudre River. A good flow of water was encountered when the well was sunk and a considerable acreage was irrigated without diminishing the supply. Later, ditches were built and the surface water in the well began to rise, and this continued with the ditch development. The water has now risen and stands within three feet of the surface, and since the installation of a motor-driven pump, the well delivers a flow of 200 inches of water day and night without diminishing, and it irrigates an entire section of farm lands. This well is a large producer for its type and the question is often asked as to how much irrigating can be done from this underground supply.

In California, over 10,000 irrigation wells have been put down and 135,000 hp is made use of for lifting the water which irrigates 300,000 acres.

It is evident that the underground waters attacked by sufficient pumping-plant capacity, with no replenishment, would be depleted, but the storage that is there to-day would water a tremendous acreage. The actual loss of water through pumping

consists only of that which gets away through the limited evaporation from the field, through absorption by entering into plant life, and by the seepage to strata beyond reach, while the factors which add to supply are the seepage losses from the ditch and reservoirs and field, the rainfall which soaks into the ground, and the large underground supply from mountain sources.

It is necessary to use all the supply available, and in many sections of the country the most practical means of adding to the irrigated section is by the raising of underground waters to the surface. It is plainly evident that if this water can be pumped and run upon the field, the efficiency of the water can be increased tremendously by each separate pumping operation, and in this second duty, the heavy losses which occur, as in canals and ditches, would not be present and the only actual loss would be that from evaporation and the actual composition in the plant.

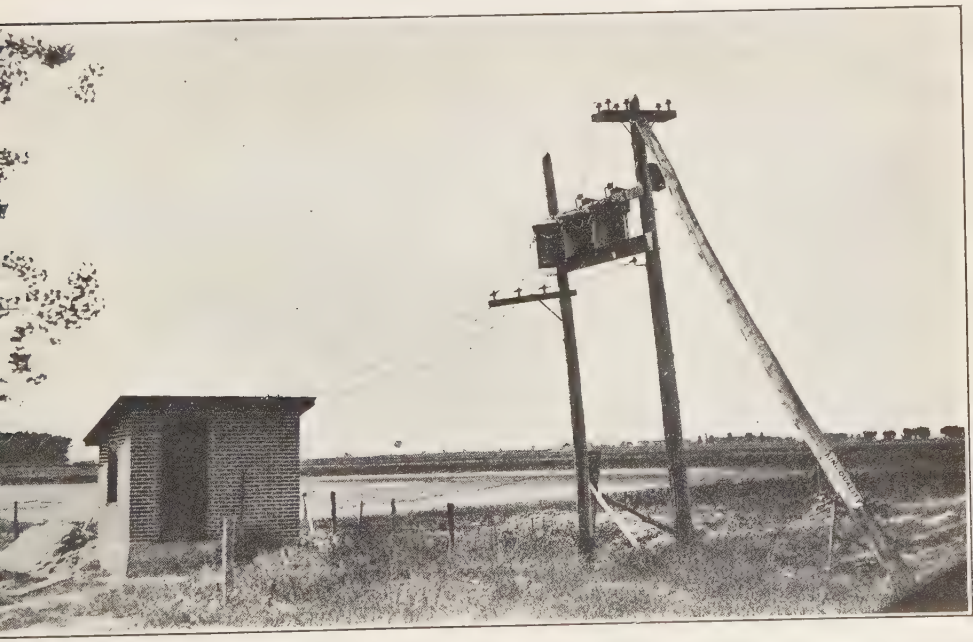
So long as abundant water was supplied to fill all needs no one was interested in the losses, and as the early appropriators measured the water at the headgates, if at all, an erroneous idea of the amount of water actually required on the field has been established. This error has been so firmly fixed in the mind of the farmer that one of the greatest difficulties experienced in introducing pumping plants is proving that the large amount of water turned in at the headgates delivers no more water on the land than the comparatively small amount lifted by the pump.

Measurement of Water

The water-users speak of quantities in different terms. The farmer usually refers to the quantity of water measured in inches, meaning the statutory miner's inch. In Colorado the miner's inch is the volume of water which will flow through a one-inch orifice under a five-inch head, where the head is measured from the top of the orifice to the surface of the water. The irrigation companies measure in second-feet, and the number of second feet is determined by the number of cubic feet passing a given point in one second's time. A miner's inch is equal to 11¼ gallons in a minute and 38.4 inches equals one second-foot.

In pumping work, the rating of a pump is used, based on the number of gallons delivered in a minute of time, and amounts of water are often given in acre-feet, which means the area of one acre covered with water one foot deep, or 43,560 cubic feet.

Pumping From a Slough Along the Platte River Bottom



claiming a Marsh Land by Draining, Also Irrigating 140 Acres Above the Ditch

One cubic foot per second flowing for 24 hours steadily will deliver practically two acre-feet. An acre-foot of water raised through the distance of one foot requires theoretically 1⅜ hp-hrs., and as 50 per cent is the ultimate efficiency of an average motor-driven pumping plant under heads of from 15 to 50 feet, a rough figure for calculating the energy required is 2 kw-hrs.' consumption per foot-acre-foot, or per acre-foot of water lifted one foot high.

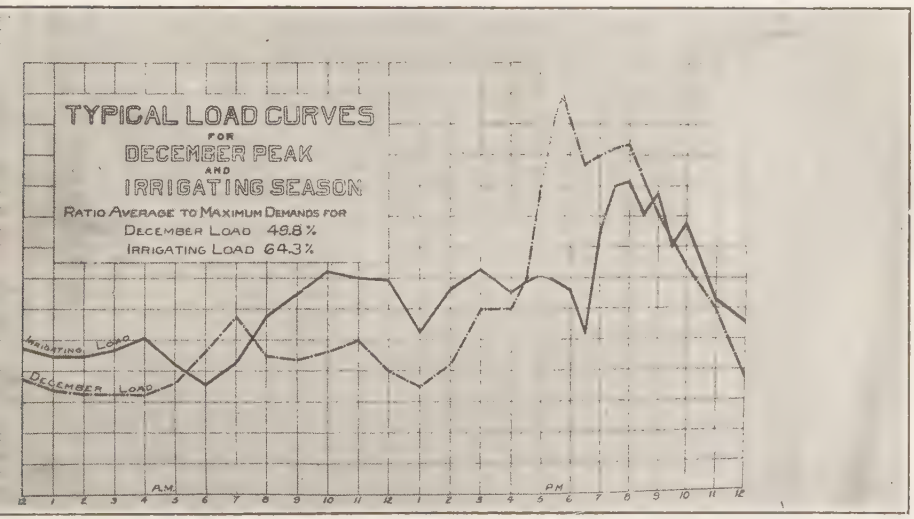
Duty of Water

The quantity of water required varies with different crops, and in planning a pumping plant it is necessary to know the quantity of water required by all the crops which may be raised, as it has been found to be of great advantage to rotate crops: that is, to change the crop from year to year and to follow certain rules wherein one crop follows another to advantage. Authorities differ somewhat as to the amount of water different crops require. John H. Gordon, who has charge of the Government experimental farm at Cheyenne, Wyoming, and who is recognized as an authority and a practical farmer, says that from three-quarters to one acre-foot of water in excess of the 14 inches rainfall there received, if properly applied, is ample for a bumper crop of alfalfa, grain or beets, and he refers to irrigation at an elevation of over 6000 feet, and where abnormally high winds prevail; and he proves his statements by producing bumper crops.

Potato Culture

Where crops are rotated, potatoes are generally planted first, and good crops are obtained from new ground. The potatoes begin to bloom about the third week in July, at which time the small potatoes begin to set, and they then require a scant two inches of water; and as this is the time the cultivation stops, it is important not to wet more than the bottom of the furrow, as wetting and drying of the hills will result in hardening the ground. A second irrigation is required ten days later, when the same amount of water is applied again. By the middle of August, the third run is required, as the potatoes are growing rapidly and taking up the moisture, and by September first the fourth and final water is applied.

Typical Feeding Yard on a Prosperous Farm



The Effect of Irrigation Pumping on Power-House Load Curve

When water can be placed upon the land this way, as actually required by the crop, four 2-in. runs will answer all requirements and eight inches of water are all that is necessary to mature the crop. When potatoes reach a certain stage, they must have water, and if they fail to get it at that time, no quantity later will compensate.

Wheat and Alfalfa

In this rotation, potatoes are grown the first two seasons, and on the third the field is put to grain, which usually means wheat in Colorado, and at the time the grain is planted alfalfa is also seeded in. The grain requires irrigation twice, the first about the 10th of June, when a 6-in. run is made, and after this the grain grows very rapidly, and before the end of June is ready for another drink, and a 4-in. run is made, so that 10 inches of water are run on in less than 30 days, throwing a demand upon a pumping plant different from that made by potato culture.

Where alfalfa is seeded in with grain, the first year's crop will not amount to much. During the two years following, the alfalfa will require four inches of water at the cutting of each crop, the cuttings coming about June 15, August 1 and October 1, respectively. There is a difference of opinion in regard to the time for watering alfalfa; some irrigate before, and some after cutting. Those who say before, maintain that by this means new shoots will be started near the ground, and after the lapse of the week or ten days required to dry the ground enough for cutting, these shoots will have been developed to afford protection to the roots.

It takes two or three days for alfalfa to lie upon the field and cure. Then it is cocked, and later put in stacks, so that a week or ten days' time elapses after cutting before it is possible to irrigate, and during this time the roots may suffer from direct exposure to the sun. If the water is put on ten days before the cutting, the evaporation losses will be less, new shoots will start, and these will grow rapidly after cutting, and the ground will have had time to dry so that harvesting can be carried on successfully.

The objection offered to watering before cutting is that difficulty may occur in attempting to cure the hay, particularly if rain should fall just following irrigation.

Alfalfa as an Enricher

The object of seeding alfalfa with the grain is partly to enrich the soil, and after the alfalfa has had its run, it is watered in the early spring and when the field is covered with a rank growth, about the 20th of May, instead of harvesting the crop, a plow is used to turn it under. Then, after harrowing the field, potatoes are put in as in new ground. When the alfalfa is turned under it is safe to assume that the soil is sufficiently enriched for five years. The effect of alfalfa on the ground as an enricher has been clearly demonstrated. The wheat crop in Colorado had gradually diminished, until twenty years ago it reached an average of but 13 bushels to the acre. The growing of alfalfa strengthened the soil by the absorption of nitrogen from the atmosphere and by rotation the yield of wheat increased until now it ranges from 45 to 80 bushels to the acre, the 80 bushels being an average of a certain 120-acre tract in northern Colorado in 1911.

Beets

After the field has been planted to potatoes, beets may follow, and if the season is dry and water is available early in the spring, it is good practise to irrigate before the plowing. In planting, beets are drilled in early in the spring about one inch deep. It is customary to water before the planting, instead of after, if water is required, and for this reason—when the seed is planted the surface is broken by the drill and leaves an opening easy for the plant to find its way. After planting, the next period when water is required is after cutting out, a process which leaves only a sufficient number of healthy plants of from one to two inches in height, and from ten to twelve inches apart, so that each plant may have ample space for growing. At this time the leaves begin to grow and offer shade to the soil about the roots, and usually about four inches of water is applied. When the beets have grown out long and slender in the ground, they will use a large amount of water in filling under ground, and at this time another run of water must be made and a foot will be ample for the season.

Construction of Wells

Having determined the amount of water necessary attention will now be given to the building of the wells.

The skill displayed in putting down a well determines to a large extent the success of irrigation pumping, and although it appears to be a simple matter to dig a hole down to where the water stands, many unproductive wells are caused by lack of engineering skill.

Two general types of irrigation wells are used—one termed an open well, where the water bearing gravel lies close to the surface; and the other the drilled, or bored well, for taking water from deep-lying strata. With the open well a 10 or 12-ft. pit is excavated to the gravel bed and this is curbed by means of concrete blocks, or stone, or plank. A metal shoe is often used, and this is placed upon the gravel and the casing built upon it, and when the curb is weighted down by piling sand bags on the top and excavation is carried on beneath, the entire casing is worked down into the gravel to the required depth.

Another scheme in open wells is to excavate the surface soil, and when the gravel bed is reached, to sink down slotted casings in the gravel by means of driving, or by sand pumps. It is good practise to put these casings down as far as possible, often from 50 to 100 feet, and when this is done in good water-bearing gravel the well will be a large producer, as the slotted openings in the casings allow of inflow of the water and still hold back all but the finer sands, which can be taken out by pumps.

This type of well is used in northern Colorado where an upper water-bearing stratum of varying thickness is found from five to thirty feet below the surface.

Where deep water is developed, the wells are drilled or bored.

Well-Drilling Outfits

The ordinary outfit used for drilling wells consists of a derrick with a drum. Around the drum a cable passes and this is led through a pulley at the top of the derrick. The drill hangs vertically within the derrick and below the pulley. The drum is equipped with power and a release so that the drill is alternately lifted and allowed to fall and strike its weight upon the bottom of the hole. Immediately above the drill two long iron links engage, and these allow the drill to strike when dropped, and act as free from the supporting tackle, and a cinch upon the cable

Shallow Wells, Connected Underground. Cement Block Caisson Sunk Into Gravel

Sinking a Caisson by Weighting Above and Excavating Below

allows the operator to turn the drill around within the hole and occupy a new position every time it drops.

When the drill has lost its cutting power by falling on loose dirt, it is withdrawn and in its place a sand bucket is let down to remove the cuttings. A sand bucket consists of a long cylinder which fits the hole and has a sort of flap valve in the bottom which allows the bucket to pass through the water in the hole and pick up the materials broken up, and when the contents are dumped upon the surface, the operator can see the nature of the stratum through which the drill is passing.

It is sometimes necessary to case the opening at the surface to keep the soil from crumbling in, but once the hole is started it can be carried down without the use of casings while drilling is being done.

Under certain conditions a rotating drill will accomplish more than can be realized by the alternate working of a drill and a sand bucket, as with this outfit the drill is forced into the ground by a continuous operation and the materials cut away are washed to the surface by the water discharged from the face of the fish-tail drill. The drill is attached to a hollow shafting through which the water is carried under considerable pressure, and extra drill shafting is added as the drill goes down.

The same schemes are used for sinking test holes as are used for sinking wells; and practise shows that a six-inch hole is a practical size for test, and this when finished is followed with the larger drill, when indications warrant the larger opening.

In putting down a hole the drill sometimes encounters quicksand, and it may be difficult to get through this to the strata further down. A common scheme made use of when quicksand is encountered is to dump thick mud into the hole and this by being churned about will plaster up the sides and stop the flow by walling off the sand; or dry cement is used and handled in the same way. When the quicksand contains much water, it is more difficult to handle, and here an iron casing is forced down, extending through the quicksand to the rock, hard pan or whatever material is found immediately below, and when the casing is forced into this and the flow of sand cut off, the drilling can be carried on to strata further down.

No single type of well can be considered best for all conditions. Where a limited supply of water is available near the

surface, it may be more practicable to put down several shallow wells from 25 to 50 feet apart and connect their pipes, than to develop an equal quantity of water from one deep well.

The depth to which boring must be done for water may not determine the lift which is required to raise the water to the surface, and usually does not in the deeper wells, as, when a water-bearing strata is contained below a ledge and receives supply from a greater elevation, the water of this strata rises in the well to find its level, and may even form a flowing well when the ledge is punctured.

Many open wells have been put down for purposes of watering cattle on the farm and then enlarged for irrigation needs by sinking slotted iron casings from the bottom of the pit, thus saving the first investment of the open well.

Slotted Casings

Where the casings are sunk in water-bearing strata the surfaces are punctured to allow a free flow of water through the casings to the suction pipes inside. Formerly these punchings were made by driving a cold chisel through the pipe, but recently machines have been designed to do this work, and several different shapes of slots are recommended, but all casings are punched from the inside out. Modern practise recommends the use of heavier materials than were formerly used, and casings are now made of iron and steel varying in thickness from No. 8 to No. 20 gauge, and usually the surfaces are galvanized after slotting, to prolong their life. The opening of the slot is outward, as stated, so that the smallest opening is presented to the gravel and any particles which can find their way through the outer opening will pass through and not clog up the passage. These slotted casings allow the water to pass, but hold the gravel back; and where water is taken from fine sands expensive screens are used.

Sand Screens

An effective screen is made by taking a steel pipe casing and punching it with $\frac{5}{8}$-in. holes to give the open area desired, after which the casing is placed in a lathe and wound with wire. This wire is four-sided. Two sides are equal. The side which is against the pipe is narrow, about one-sixteenth of an inch, while

the side presented to the sand is three-sixteenths of an inch, or three times as wide. The wire is drawn or wound around the pipe and soldered to keep the outer opening presented to the sand a definite predetermined one, this being governed by the size of sand encountered. As with the slotted casings, the smaller opening is outside, so that anything which passes through will find an easier passage inside and not clog up the strainer.

The fine sand contained within the gravel is pulled into the casing, leaving the coarser sand and gravel banked against the sides to act as a further strainer, and this action accounts for the usual experience of finding a well producing larger quantities of water as it continues to be used.

A strainer casing of this kind, 12½-in. inside diameter, will cost $6.00 per running foot.

In any well, it is necessary to remove a quantity of sand by pumping before the flow is permanently established, and this is taken through the casing, no strainer ordinarily being used. Sometimes a week is required to do this work, and it necessitates a special pump designed for handling quantities of sand.

All this depends largely on the nature and fineness of the strata, and one of the difficulties in developing this pumping work is the uncertainty of what will be encountered in the way of water-bearing strata below the surface.

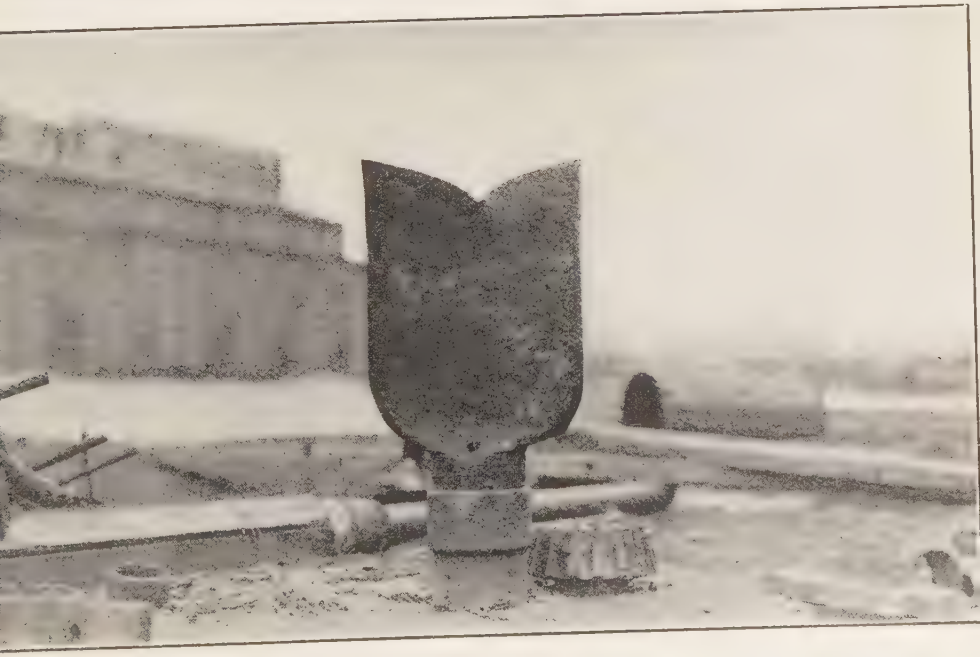
Water or No Pay

In Colorado the well diggers ask the farmer to assume the uncertainty of securing water, and contract only to put down a hole at a fixed price per foot.

The Northern Colorado Power Company is considering the advisability of offering to all landholders along its lines a proposition under which the Power Company will agree to put down wells and produce a definite amount of water, and to back the proposition with the agreement that there will be no charge in case of failure to produce water. For example: A contract will be signed for five years' use of power and for payment of the well to the Power Company, conditioned on the Power Company producing a minimum of 40 statutory inches of water, as measured by a weir, and this for a reasonable length of time to show the reliability of the flow.

If no water is found at 30 feet, and the underground forma-

Sinking Concrete Lined Pump Pit



Fish-Tail Drill for Sinking Wells

tion is not known, a test-hole will be continued down and a record secured of the lower strata; whereas the individual owner would probably be discouraged and abandon the work. Notes will be taken as the boring proceeds and definite information can be secured, so that the company will be in better shape to guarantee results.

The Power Company has equipment for working economically and has secured the services of the most experienced men, and all the materials used, such as casings, screens and piping, are arranged for by the more advantageous purchasing facilities of a larger company, while the power required for doing the work is available from the lines adjacent to all prospects where this offer will be made. An arrangement such as this will remove all uncertainty from the proposition on the farmer's part, as information regarding pumps, motors and equipment is of a definite nature.

Types of Pumps

Centrifugal pumps are more used for irrigation work than all the other types combined. These pumps are made in various forms, with either vertical or horizontal shaft, to suit the particular conditions to be met. They are made to handle from the largest to the smallest volumes, and they vary in dimensions from one inch to sixty inches in their discharge, and are used to raise water through a distance of from a few inches to several hundred feet. Centrifugal pumps are oftentimes compounded, the discharge of one leading to the suction of the next, with several runners on one shaft.

Vertical type pumps are largely used in wells, as there is a rise and fall of the water level and the vertical pump admits of easy adjustment to fit these needs.

In the open well, a built-up structural steel framework to which the pump is attached, carries the drive-shaft to the surface and takes its power from a belted motor properly located and housed at one side. This arrangement does away with any shaft alignment troubles and allows the pump and shafting to be withdrawn without disturbing or interfering with the motor or connections. In some instances a direct-connected outfit with a vertical type of motor is installed at the surface and a direct-connected horizontal rig is placed at the bottom of the well

where there is no danger of a rise of water which might submerge the motor.

Centrifugal pumps having 8 to 12-in. openings and raising water 10 feet or more, operate under favorable conditions at 75 per cent efficiency, and manufacturers will guarantee as much; but it is necessary that pumping plants be properly installed in order to secure economy. Failure to operate at proper speed, or failure to handle the quantity designed for, may easily produce most discouraging results. The friction head must be allowed for, and it is found in practise that the enlarging of the pipes on both the suction and the discharge side is advantageous.

Where it is possible to get a pump below the surface of the water so that gravity supplies the suction this is done and a vertical-type pump is installed; and where it is possible to place the pump close to water level, but not below it, the horizontal outfit is put in, and a 12-ft. suction lift is about the practical limit at an altitude of one mile. To gain economy, the pump must be designed to fit the lift, as the power consumed at a lower lift will be greater than when pumping at the lift for which it was designed on account of the larger volumes handled, and the motor may be excessively overloaded when an ordinary centrifugal pump is used.

A pump has recently been brought out which delivers water at various heads with very good economy throughout its range, and such a pump is useful where water is to be delivered by a pipe line at several points along the line or under different heads.

Housings

The buildings covering the wells and pump are usually well constructed, being made of concrete blocks with cement floors and fireproof roof, with windows and doors which lock, and it is believed important to get the farmer to furnish housing presenting a good appearance, as the cost is small. When built the owner prides himself on the appearance of the outfit and will take better care of the plant equipment than when the housing consists of a few boards to keep out the weather, with a wet plank for a floor.

Cost of Pumping Plant

The cost of the typical pumping plant complete for which the

farmer makes an investment for supplying water to a 160-acre tract, is as follows:

Excavation of well-pit 12 ft. deep, 12 ft. dia. and excavation for two suctions 25 ft. from center of the well	$ 55.00
Three 12-inch slotted casings of No. 16 gauge, each 30 ft. length, installed	180.00
Concrete linings	42.00
No. 7 horizontal centrifugal pump with capacity of 1200 gallons per minute	225.00
15-hp motor, 2300-volt, 60-cycle, 3-phase, 1200 r.p.m., installed	325.00
Wiring, switchboard panel, including switching and protective devices	52.00
Piping, three suctions, discharge gate valve, priming pump, discharge piping	137.00
Housing built of concrete complete	115.00
Incidentals	25.00
Total investment	$1156.00
Investment for completed plant per acre	$7.23

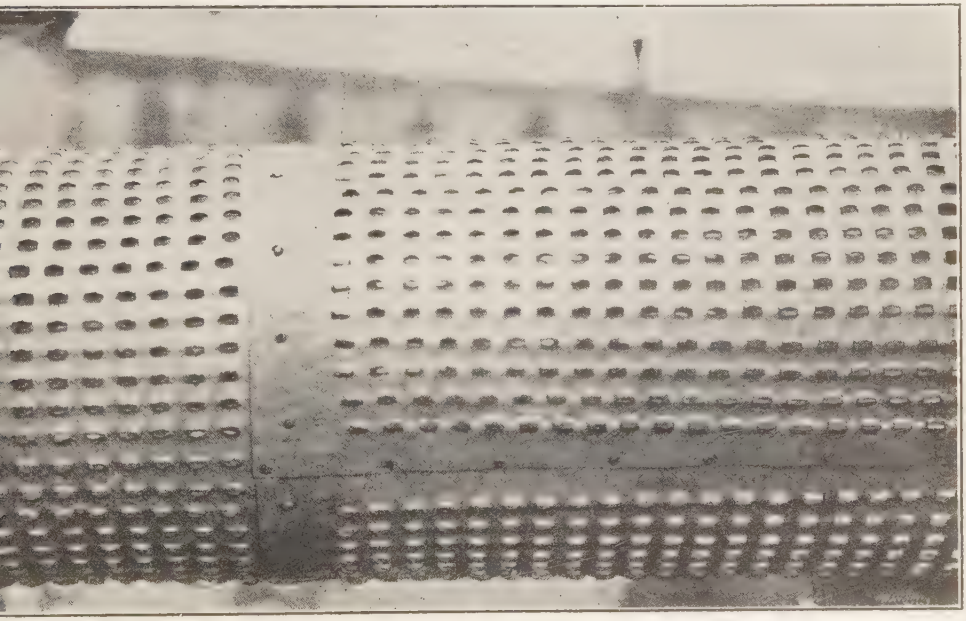
Kinds of Power Used

The different kinds of power used for driving pumps are electric motors, engines and windmills, the engines using gas, oil or coal for fuel; and competition is not strong where electricity is available, as the advantages of the self-oiling 3 phase induction type motor increase with the distance from repair shops.

Responses to inquiries sent to 125 pumping consumers on the northern lines who have used electric drive as well as other forms of power, as to the advantages of the electric motor over other forms of drive, are that THE MOTOR ALWAYS RUNS WHEN WANTED, and it is an indisputable fact that the electric motor requires the least care of any form of power available for this work. Practically one-half of all of the motor installations in northern Colorado have supplanted engines, and there has never been a single change by which the electric motor has been displaced by any other form of power, nor has there ever been an electric pumping plant installed which later was discarded. When the motor is started the pump-house is closed and the farmer goes about the work of distributing the water in his fields and provides no further attendance for his plant.

The bulletins from the Experimental Stations of the Department of Agriculture show that on all the plants for which they have compiled data, the electric motor performs 24 per cent more work than the oil engines of equal rated capacities.

p Structural Steel Framework for Carrying Vertical Shaft From Pump to Surface



Common Type of Slotted Casing

Windmill Pumping

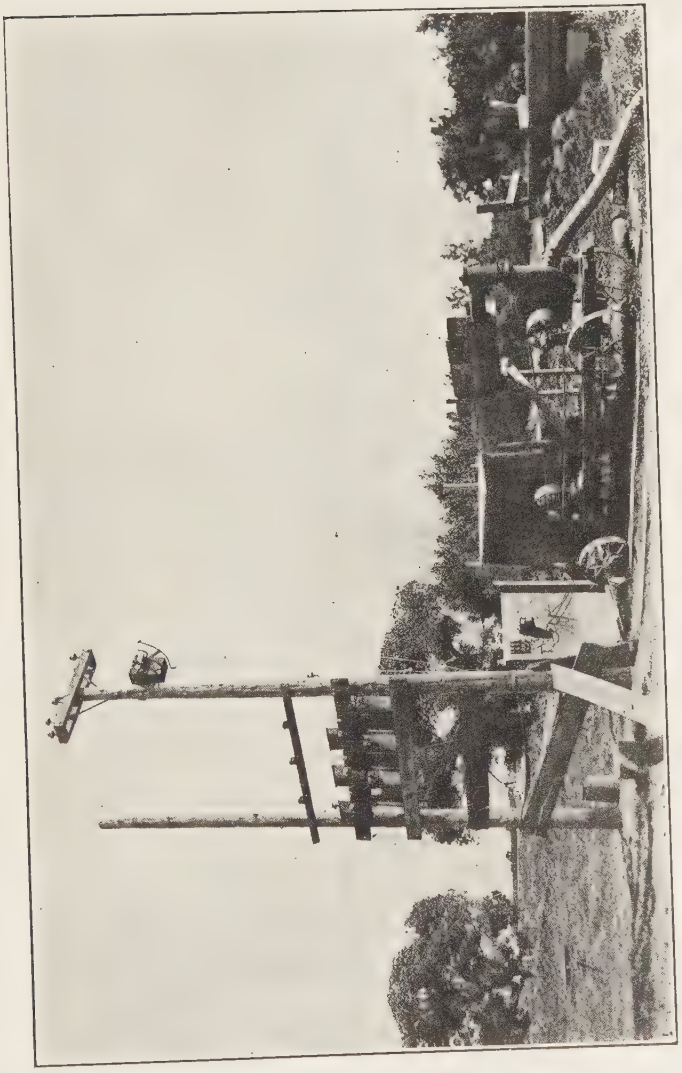
The Government has investigated the pumping of water by power from windmills, particularly on the plains east of the Rocky Mountains and near Cheyenne where, on the open prairie, with almost constant winds, conditions are most favorable. Here six mills of from 12 to 14 ft. diameter were put into service and accurate records kept of the water pumped and of the cost of pumping, including maintenance and repairs. The capacity of the mills, about one-tenth of one horse-power each, was so small that the equivalent cost per hp-hr. used exceeded 20 cents and proved the impracticability of such installations for irrigation work. Electric motors are now being installed on this Government Farm to supply the irrigation needs.

The matter of attendance spoken of before has had the attention of the Government engineers. In investigating the cost of operating gas and oil engines of small capacities, Government Publication No. 1297 states "it has been found that a pumping plant having a gasoline engine will require two men, one for the day and one for the night, with a small engine of, say, 30-hp capacity."

Mr. V. M. Cone, of the Experiment Station at Fort Collins, Colorado, who has had wide experience in pumping work, states that the great advantage of the electric plant is in the slight attendance with which it may be operated and especially the reliability of the plant. He states that when stationed in California two electric pumping plants near Fresno were under his charge and were operated continuously from March until September with entire satisfaction, no repairs, and without more than five minutes attention in a day. The same report brings out the fact that the small steam engine and gasoline engine from 15 to 50-hp are practically equal in cost of operation, although these figures might vary in different sections of the country where fuel values differ. The figures from which these conclusions were drawn cover an entire season's work on hundreds of pumping plants in actual operation.

Transformer Capacity Required

The pumping load is of such a nature that ample transformer capacity must be provided when transformers are made use of, as the pumps when started will operate continuously for several weeks on a steady, constant load, allowing of no time for cooling



A Portable Irrigation Pumping Plant

of apparatus if overloaded. For this reason, transformer capacities ranging from 1000 to 1200 watts are installed per hp of capacity of motors.

The advantage of the 2300-volt motor is apparent, relieving as it does a heavy expenditure for transformers, and where the installation reaches 15-hp capacity or more, the 2300-volt motor is installed if secondaries of this voltage are available, and the use of these higher voltage motors has proved entirely satisfactory.

The Farmer as a Consumer

The farmer as a consumer is of the most reliable type and an investment made to serve him is safeguarded. The farmer is not an agitator and is not opposed to corporations. He sees the advantage of having outside money invested in the country which he occupies, he pays his bills promptly, and once connected finds many added uses for electric power on the farm. He readily sees the advantage of pumped water and realizes the great gain in getting his water just at the time he needs it. He recognizes another marked advantage in the use of pumped water over water from the reservoir and ditch, and that is, the fact that the well water is uncontaminated.

Advantages of Pumped Water

Not only does the ditch bring down and deposit a large amount of sediment, which may or may not be detrimental to the farm, but it carries quantities of seeds of obnoxious plants and weeds, which require a large amount of labor for their extermination later on.

A very strong recommendation for the use of irrigation water taken from wells rather than from reservoirs and ditches is set forth in a letter secured through the courtesy of President Chas. A. Lory, of the Colorado Agricultural Experiment Station at Fort Collins, transmitting a letter from C. L. Fitch, who has been delegated by the Government to determine the cause of the potato failure in this western country, particularly last year when there was no crop in Colorado.

This letter is of such importance that it is reproduced with this report.

Potato Blight

For several years the potato crop in certain sections under

An Old Bucket Lift Connected to Electric Drive

certain ditches experienced blights, more or less severe. Last year the water conditions were abnormal, due to shortage, and potatoes were a failure. There was practically no crop. The matter was of sufficient moment for the Government to immediately undertake to find the reason and the work was delegated to Mr. Fitch. The blight was caused by a kind of fungus growth which attached itself below the ground and just above the tuber. The experts made a careful study in the field and reproduced conditions in the laboratory. They found that they could promote, retard, and stop the growth at will, and that conditions of temperature and moisture were the factors which controlled; —"excess of soil temperature, or excess of moisture, and especially both in combination, will always bring on the disease."

Last summer the reservoirs were low, the water warm, the temperature of the atmosphere was high and all conditions were present necessary for the epidemic which ensued. Mr. Fitch found that soil temperature above 85 degrees when associated with a high percentage of moisture, caused disease; that soil temperature below 80 degrees without excessive soaking produced a safe condition; that pumped water averaged 60 degrees F., while water from the normal reservoir in July and August stood at 75 degrees or more. In the letter it was pointed out that it is practical for a farmer to use a thermometer to determine the temperature of the soil and learn whether he can safely use the water from the reservoir, or whether he must use it sparingly and at night, or should use pumped water from a well.

In two adjacent potato fields in northern Colorado, the one which took water from the reservoir lost its crop, realizing only five bushels to the acre. The other, which pumped water from a well, secured a yield of 85 bushels to the acre. Both were 160-acre tracts and similar, with the exception of the water.

This is a matter of keenest interest to the farmer and may mean success or failure to him.

Advantages of Irrigation Pumping

The greatest advantage of irrigation pumping from the farmer's point of view is that a pumping plant will give him WATER JUST AT THE TIME HE WANTS IT, and this is a more important factor to him than the saving of the money effected. It is the exception to get water just at the time it is wanted when

watering from a ditch, and necessarily so, as ditch riders and water superintendents must serve all alike. When water is turned into a ditch, it must be run in quantities to secure economy, and it is not possible that every man along a ditch will be similarly situated with regard to the progress of his work, so that all will require water at any one time. When a run of water is needed the farmers call a meeting and make known their requirements, 40 per cent being the number usually obliged to sign to get a run of water from a reservoir. The Board of Directors determine the amount of water which may be run and also the order in which the different divisions of farmers shall be served.

Reservoir water is usually run for two or three days to one division and then changed to another, and under these conditions individual requirements cannot be given much consideration, for it is not economy to run a ditch but partially filled.

Cost of Pumped vs. *Ditch and Reservoir Water*

To show an absolute comparison between the cost of water pumped and water served by a gravity system, figures are taken from northern Colorado, where old-established ditches are serving large acreages of lands and electric motor-driven pumping plants are lifting irrigation water for 20,000 acres.

The market values of Ditch and Reservoir Rights as of the spring of 1912 are given by the officers of the companies as follows:

NO. 2, OR OLD COLONY DITCH

Cost of ditch water for 160 acres	$7,000.00
Cost of reservoir water for 160 acres	2,000.00
	$9,000.00

LARIMER AND WELD, OR EATON DITCH

Cost of ditch water for 160 acres	$4,400.00
Cost of reservoir water for 160 acres	2,800.00
	$7,200.00

WATER SUPPLY AND STORAGE DITCH

Cost of ditch water for 160 acres Ditch and reservoir water construction	$6,400.00

These rights as quoted are on the basis of water for 160 acres, and the farmer pays outright an average of $7,533.33 for his perpetual rights to this amount of water, and also as an

expense for water he must figure an annual interest charge on his investment, at the prevailing rate of interest in his territory, which is 8 per cent, for he could loan the $7,533.33 at 8 per cent on good farm lands, if the money were not invested in these water rights.

The $7,533.33 per 160-acre right, equal to $47.20 per acre, is, however, not enough to take care of the investment made by the companies, as the Ditch and Reservoir Companies have interest charges to meet on very large bond issues covering the whole development, hence an assessment is made against the shareholders to cover the interest charge, and this for the past three years has amounted to $1.68 per acre. A further assessment or charge is made against the shareholders for the annual upkeep of the property, this last amounting to an equivalent of 40 cents per acre.

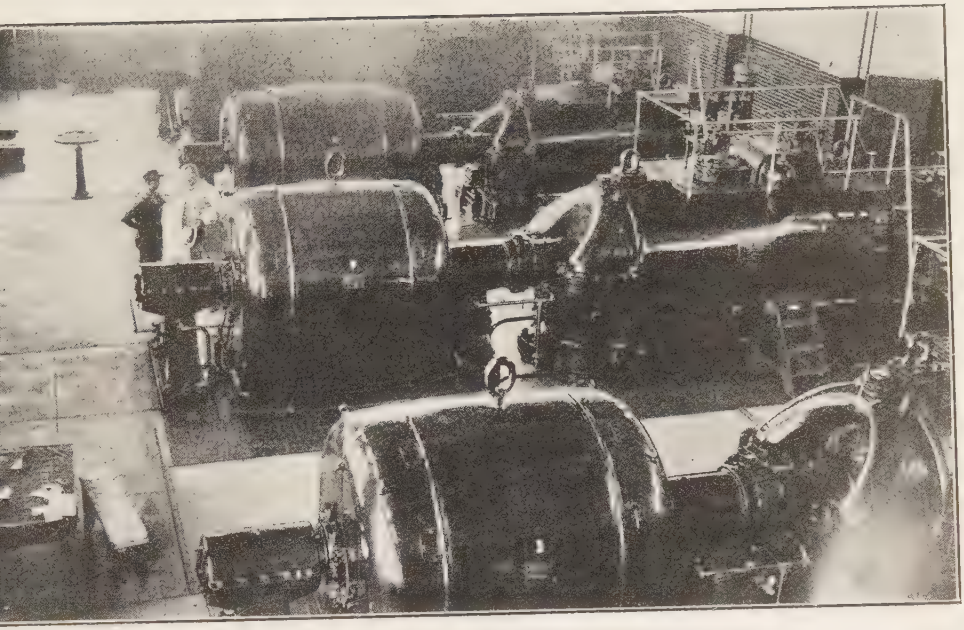
The actual cost, then, to the farmer for his water, as compared with a similar cost for pumping, is:

	Per Acre
8 per cent interest on original investment of $47.20	$3.77
Assessment on account bond interest, etc.....	1.68
Maintenance cost	.40
Total actual cost for water per season.....	$5.85

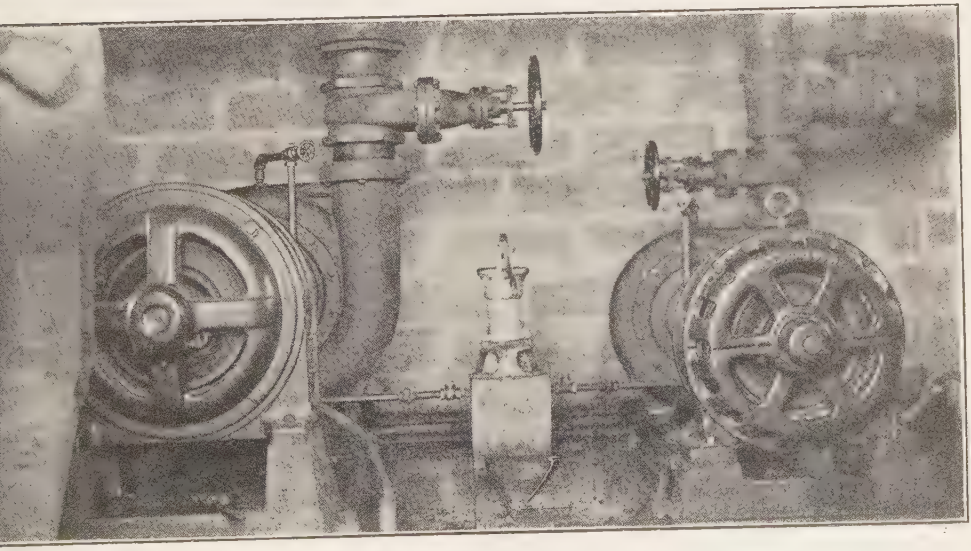
This assessment for the payment of bond interest has been found to be inadequate in many cases to take care of the obligations to be met, and in casting up the prospects for the future it is seen that this assessment will have to be materially increased, or else the companies will find a greatly enlarged obligation at the end of a period of years.

The total cost of pumping water is much less than its cost from ditch and reservoir. For a pumping plant, the farmer also makes an investment, and here not only is the interest figured in, but 3 per cent is added for depreciation. The average investment for pumping plant, including cost of well, cost of motor, pump, housing, wiring, piping and the plant complete, is $7.23 per acre, as shown in detail earlier.

The average lift on 90 pumping plants supplying irrigation in the territory is 23 feet. The average efficiency of motor and pump is 50 per cent. The average amount of water supplied to the field per year is one acre-foot.



Turbine Room at Lafayette Power-House



Direct-Connected Horizontal Pumping Plant—Two Units

The interest charge is figured the same in either case, at 8 per cent, which, with the added fixed charge of 3 per cent depreciation, gives a total of 11 per cent.

11 per cent on $7.23 equals	.80 per acre-yr.
$\frac{43{,}560 \times 2 \times 62.5 \times 23 \times .764 \times .03}{1{,}980{,}000}$	1.40
	2.20 per acre
Oil, waste, maintenance and attendance	.27 per acre
Total cost, including interest, depreciation and all operating costs	2.47 per acre
as against $5.85 from ditch and reservoir	

The gravity water costs practically twice as much as the pumped water under these conditions.

One manager of a large sugar factory states that he can afford to incur an expense of from $8.00 to $12 per acre per season for water in raising sugar beets, and he is now putting in a large number of deep wells to irrigate 37,000 acres of beet land.

Cost of Raising Different Crops

The actual amount of money which can be expended profitably for water depends largely on the value of the crops which can be raised. The Government has published figures on the cost of raising certain crops and these have been corrected to Colorado conditions by the best posted men in Colorado.

SUGAR BEETS

Revenue based on a yield of 13.5 tons per acre at $5.50 per ton		$74.25
All expenses		
Plowing 9-in. deep	$2.00 per acre	
Preparing seed bed	1.50	
Planting	.50	
Seed, 15 lbs. at 10 cents per lb	1.50	
Rolling	.50	
Cultivating 4 or 5 times	2.50	
Bunching and thinning	7.00	
Hoeing 2 or 3 times	2.00	
Plowing out beets	3.00	
Topping and piling	9.00	
Siloing 25 per cent of crop	1.70	
Depreciation on machinery	1.00	
Hauling 3 miles	8.50	
Interest on investment	16.00	56.70
Balance which could be paid for water		$17.55

POTATOES IN GREELEY DISTRICT

Revenue based on yield of 100 sacks at .725		$72.50
Expenses		
Plowing	$2.00	
Harrowing	.50	
Planting	1.50	
Seeding	9.00	
Cultivating	1.50	
Sacks	7.50	
Harvesting	8.00	
Marketing	6.00	
Interest, 8 per cent on $200	16.00	52.00
Balance which could be paid for water per acre		$20.50

The Northern Colorado Power Company's Plant

The farmers have realized that a serious situation confronted them in regard to water, but up to four years ago there was no definite solution offered.

In 1907 the Northern Colorado Power plant was built to furnish electric power to all the towns in northern Colorado and to develop the business of pumping irrigation water and supplying the power demands upon the farm. The territory covered by transmission lines and lower voltage leads is represented by 3000 square miles, enclosing 2,000,000 acres, over which ditches and reservoirs have been built. The field is almost exclusively agricultural, and acts as the principal source of supply for the city of Denver and of Cheyenne on its north, besides shipping large amounts of produce to eastern markets, and it constitutes one of the most fertile agricultural regions in the west. This territory even with the population of its towns will average only 30 inhabitants to the square mile, and although development has been rapid during the past 10 years, it offers unlimited opportunity for further growth.

The main power station is located 20 miles north of Denver in the center of the Northern coal fields, between the towns of Louisville and Lafayette. The main generating station consists of a Parsons turbine plant, with two 2000-kw, 60-cycle, 13,200-volt, 3-phase turbo-generators and two 1,500-kw, 25-cycle, 11,000-volt, 3-phase units, operating on single-phase for an 11,000-volt interurban railway with 42 miles of track between the cities of Denver and Boulder. The boiler plant equipment consists of ten 411-hp Franklin boilers equipped with Foster superheaters, Green economizers and induced draft. Altburger

atmospheric condensers are used, and a large artificial reservoir with 26,000,000 cubic feet capacity furnishes ample water for condensing purposes.

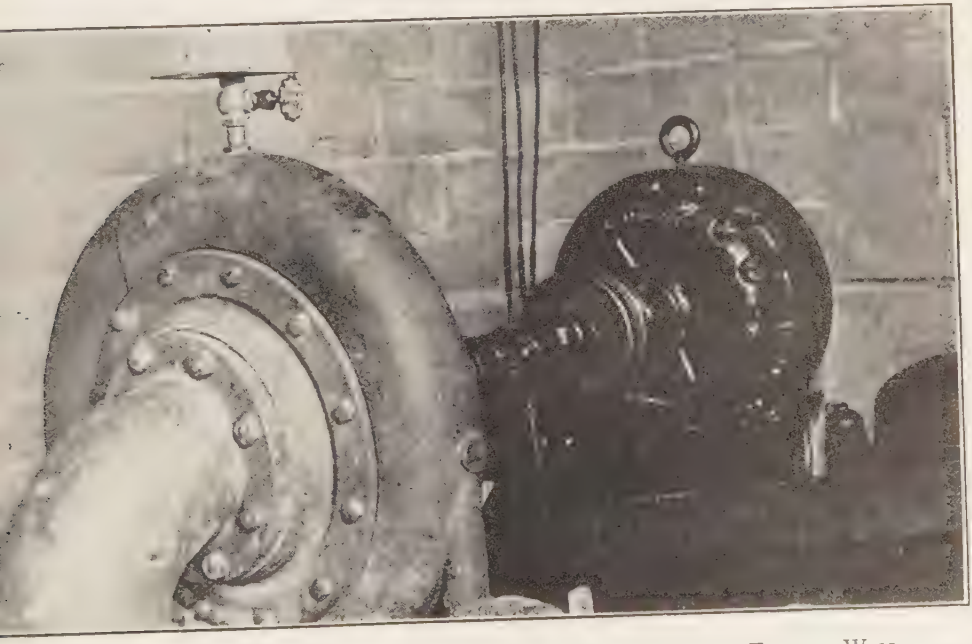
The Power Company owns the coal mines adjoining the power plant, where 50 years of normal coal supply are in reserve. The coal comes to the conveyor by gravity from the tipple of the mine, is elevated to the storage bunkers, passes through the automatic stokers and the ashes are dumped to cars below without being touched by hand.

The step-up transformers raise the voltage from 13,200 to 44,000 volts and transmit it over a 120-mile transmission line built in the form of a loop, forming a backbone for a distribution system between Denver and Cheyenne. Substations are located 20 miles apart, where current is stepped down to 6600 and 2300 volts, and these secondary lines cobweb the system. At each substation three sets of pole-top switches control the line, one into the substation and one in each direction from the substation, so that in case of any trouble on the line, or in case of repairs on the transmission line, a section can be cut out between substations without interfering with any distribution district or with the balance of the line. This is equivalent from any operating standpoint to a double transmission line and eliminates all shut-downs.

Practically all of the transmission line is built upon railroad rights of way, on which the privilege of operating gasoline motor cars is granted for patrol, and one patrolman easily takes care of all the high line. The country near the line between the States of Wyoming and Colorado is least settled, but has a large supply of water near the surface which can easily be developed by means of shallow wells, and this country is rapidly being settled. The lines in northern Colorado will soon be loaded by the developments further south, and this will necessitate connecting through with the Cheyenne power plant to enable feeding from the north as well as from the south.

Where a group of pumping plants has been secured away from secondary lines, an out-door substation has been installed. These out-door substations are inexpensive housings for in-door type 44,000-volt transformers equipped only with air-cooled choke-coils and horn-gaps with pole-top switches outside the substation and disconnecting switches inside, and no attendance is provided for these installations.

Steam Turbine Generating Plant, Located 20 Miles From Denver



Direct-Connected High-Voltage Plant Supplying 240 Acres From a Well

Lightning conditions are severe at an elevation of one mile or more with Colorado's dry climate, as the static builds up to a tremendous differential before discharging, and when it does let go, it plays no favorite between the different types of apparatus for protection, but these isolated substations have not suffered any damage.

Developing Irrigation Pumping Business

The business of developing irrigation pumping is different from anything the commercial man experiences in town. He finds the farmer of the opinion that electricity is a proper thing to operate the shop, or light the house of the city man, but he may never have considered the possibility of its use upon the farm. Oftentimes the thought of taking sufficient water for irrigation work from the ground below his land is new to him. He is willing, however, to be shown. When properly approached he gives more time and careful study to what is offered than any other class of men whose time is equally as valuable. He reads and studies and he knows the values of the things he wants. The average farmer in northern Colorado adopts a better system in handling his business and accounts and knows much more regarding costs of operation than does the average man in town. The prospects are not close together and time is required to call on individuals, and several calls must be made on every prospect before a contract is secured. The farmer wants to talk with others using pumps, he has to see a firm regarding putting down a well, he figures with the companies who handle pumps and the agents handling motors, and these are not available at a moment's notice through the telephone, as in town.

The Northern Colorado Company has made a canvass of all land-owners along the line, has sent each a form to be filled out to show the acreage under ditch, the acreage above and the dry land for which no water is available and has received prompt and intelligent replies. From this list preferred prospects are taken for the commercial men to work upon. Local advertising in the newspapers, reliable data compiled in pamphlet form and follow-up letters all receive more attention by the farmer than by the man in town. Regular attendance at all the grange meetings, with demonstrations of pumps in actual working, showing the handling of large quantities of water, is effective. Billboard

advertising calling attention to the location of each pumping plant along the highway continually reminds the farmer that his neighbors are getting ahead of him in scientific farming. Lists of farmers having plants are frequently sent out through the mail, with data showing detailed costs of building plants and the cost of running them when finished, and these help to convince the farmer of the cheapness of this means of getting water. But these alone will not secure the business. The use of an automobile for taking prospects to visit operating plants and having one farmer, who already operates a plant, talk to his neighbor, brings more direct results than any other plan the commercial man adopts. The commercial man, however, must be there and he must know the irrigation work, and must later make surveys to get the best location for the well and plant. He figures up the estimate of the cost of well, pump, motor, wiring, housing, piping and the ditching, together with the cost of operation and shows final cost of placing an acre-foot of water on the land.

The development of power used on the farm progresses rapidly when introduced. A typical section of land is shown on which a line was extended in the Spring of 1911. The figures show the connected load one year after this line was built. The area occupied was one mile square, the line required was 2.2 miles long, the load connected was 77-hp, which yielded an annual revenue of $893 on off-peak load.

Contract

The form of contract entered into is attached to this report. The basis of charge for current is a readiness-to-serve charge plus a meter rate.

The readiness-to-serve charge starts with a $1.00 per hp per irrigation month, on the smaller sizes, with a lesser charge for added installation, reducing to 25 cents per hp on the last increments of demand.

The meter rate starts at 3 cents per kw, and this applies for the first 2000 kw-hrs. used per month, the rate decreasing with successive increments of use, the last being at the rate of 2 cents per kw-hr. The kw-hr. part of the rate is subject to a discount of 10 per cent for prompt payment.

As line extensions are frequently made to serve an individual customer, an annual minimum irrespective of consumption or

demand is made. This minimum is based upon the construction cost for line extension, and as the country lines will average $600 per mile, where No. 6 copper is made use of, the guaranteed annual minimum is taken on the basis of $300 per annum per mile of line required. Provided other customers are added to this line, the minimum is prorated with the new customers, and both the company and the first customers are benefited by the added business.

An alternative is offered to the prospect where he advances the construction costs and is rebated a percentage of his yearly bill, and on this contract no guaranteed minimum is required.

An optional rate is offered to the consumer on which a minimum bill is charged without a readiness-to-serve.

The monthly minimum is $1.00 per horse-power of installation, and the meter rate is:

5	cents	per	kw-hr.	for	first	500	kw-hrs. used
4½	"	"	"	"	next	500	"
4	"	"	"	"	"	1000	"
3½	"	"	"	"	"	3000	"
3	"	"	"	"	all consumption over 5000 kw-hrs.		

per month, with a discount on the meter rate of 10 per cent for prompt payment.

All pumping current is sold upon these rates and no flat rate is made, as it has been demonstrated that a flat rate is beneficial neither to the customer nor the Power Company.

The readiness-to-serve charge on pumping business is made during the irrigation months, and these are specified when the contract is made out.

Effect on Load-Curve

The pumping business fits admirably into the load-factor of a central station supplying commercial and municipal requirements, as the pumping load helps to fill the valleys of both the daily load-curve and the annual load-curve, since the work of irrigation is ordinarily carried on in the daytime, or at least off-peak, and this during the summer months from May to November 1.

On the Northern Power Company's plant the kw-hours' output of the plant is greater in the summer months than in the winter, although the demand is much larger in the winter than

in the summer, and this allows of a large increased connected load of pumping work without requiring additions to plant, line or substations. The effect of the pumping business is fully shown by a load-curve, characteristic of the output at the power-house of the Northern Colorado Power Company during a peak-load day in December and an average output day during the month of August, when irrigation demands are heavy for late water.

Increasing Demands for Water

When it is considered that appropriation of surface water in many western States exceeds the visible supply, the necessity of putting every drop of available water—whether surface or underground—to beneficial use is plainly evident, and as the rights to water from below the ground will in a measure be determined by the priority of application to such use the farmer readily sees the advantage of getting his plant installed before that of his neighbor. The States lying west of the Missouri River show an increase in population of 1,000,000 people a year for the past 17 years, with an increase of 42 per cent in 10 years, as against a rate of increase of only 17 per cent in the remaining 31 States. These figures show an increase with which irrigation must keep pace, which means a similar increase in demand for water.

Power on the Farm

The work of pumping is but one use for power on the farm, and an analysis of the possible power consumption on the farm shows a tremendous use as compared with ordinary estimates. Farm power is expensive, as the fuel costs are high. It is a work of education to present the power problem to the farmer, to show him that he is already a consumer of large amounts of power, using animal power and manual labor at costs which are prohibitive when electric current is available. How many farmers consider the power equivalent of money spent for horse feed? It costs $7.00 a month for seven months to feed a work-horse if the farmer has the feed, and if he has to buy the grain and hay the cost will be increased to $10 with $3.00 a month for the other five months.

A good work-horse represents an investment of $150, and such a horse is good for ten years' work if nothing happens in

the way of accidents or ill luck; and on this basis the cost of animal power is several times the cost of electric power, with the disadvantage of having feed bills when no work is done.

Among the possibilities for the use of electric power on the farm, the work of cutting and grinding feed for stock is a close second to that of irrigation.

Reasons for Feeding

The cultivation of the range lands has made the raising of range cattle more difficult, and a careful system must be worked out in order that the half-finished range cattle may be brought to the feed pens and finished for the market. There is always a ready market for finished stock, and the farmer may devote most of his time after the harvesting season in this very profitable way.

The soils in the western and arid States possess a very small capacity for holding moisture, due to the lack of humus. This characteristic may be materially increased by the addition of fertilizer taken from the feed pens, with the result that when the products of the farm are worked up and fed to farm stock, not only are the fields enriched, but a very material retention of moisture in the soil is secured.

The problem of maintaining a standard of productiveness in the soil is one that requires careful study on the part of the farmer.

Methods of Feeding

A few years ago the live stock on the farm, whether for the market or for dairying purposes, were fed from stacks, or the materials were placed in bulk where the animals could reach them if they chose. The cattle were extremely wasteful and when fed in this way, as a rule, wasted at least 50 per cent of the roughage. Left to themselves they would eat what most appealed to them and throw the rest aside or trample it under foot. In the winter months, the feed of the cattle must be adapted to climatic conditions and the ration changed to fit these conditions. In extremely cold weather, the carbo-hydrates must be increased, while the protein remains the same.

The Balanced Ration

A balanced ration is a combination of foods which will produce the best results by giving to animals such elements of food as will assimilate and produce a maximum of weight, heat or butter fat, as desired. Balanced rations have been worked out to produce the best kinds of foods available and for all kinds of stock, and the results of feeding according to such rations are so established that theories along these lines have been displaced by proven results.

Having determined the proper mixtures to secure the best results, it is necessary to provide a way to induce the stock to eat them, and the only way that this can be accomplished is by grinding up the food so thoroughly that the individual parts cannot be separated. This is done with special mills designed and built for chopping up and grinding alfalfa, peas, hay, straw, sheaf grain and beet tops, and for mixing in the syrup from the sugar factories.

Quantities of roughage, such as straw, pea vines, corn stalks and the like, have large food values if prepared so that stock will eat and relish them, and this is easily accomplished by grinding mills wherein they are reduced to such a state that the component parts cannot be separated.

In northern Colorado, 1,000,000 sheep and 500,000 cattle are fed and fatted for the market every year, the active feeding period beginning early in October and continuing about four months.

Feed Available in Colorado

Colorado alone has produced yearly for the past few years about 500,000 acres of alfalfa, 500,000 acres of wheat, oats and barley; 120,000 acres of beets, and in addition to these, large quantities of other coarse foods, which may be used for the roughage of the balanced ration.

The possibilities for the use of power in grinding and mixing feed for cattle are shown in the combined tonnage of beet pulp, beet tops, alfalfa straw and pea vines produced in Colorado in one year—in amount, about 5,000,000 tons. Assuming the feeding period to be 100 days in length and that a steer weighing 1000 to 1100 pounds will consume about five tons of this feed during the period, it can be seen what a tremendous saving of feed can

be made by grinding and mixing. The common ration per day for a steer weighing from 1000 to 1100 pounds is:

100	pounds	beet pulp.....	4	cents
3	"	cotton seed cake..	5	"
5	"	alfalfa	½	"
10	"	straw	2	"
8	"	syrup	4	"
Labor			3	"
Power			.0202	"

making a total cost of this ration .1852 cents per day.

Beet pulp has about 40 per cent of the weight of the sugar beet, in the form of a wet mass containing perhaps 90 per cent water. The dry substance of this pulp contains 10 per cent protein and about 90 per cent carbo-hydrates and fat. Alfalfa contains from 10 to 12 per cent protein and from 36 to 40 per cent carbo-hydrates and fat. Fresh beet tops contain about 15 per cent dry substance, about 2 per cent protein and 8 per cent hydrates. Molasses is nearly all carbo-hydrates. Corn contains about 8 per cent protein, and 66 per cent carbo-hydrates. Thus it can be readily seen how a perfectly balanced ration can be produced for cattle feeding.

Professor Henry, in his book "Feeds and Feeding," makes the statement that "about 1000 lbs. of grain will be required for 100 lbs. of gain with well-fattened steers, on the average, besides 500 pounds of coarse food in the shape of hay."

With a well-balanced ration, the farmer is able to make a 100-lb. gain at the rate of 1½ lbs. per day, and at a much less cost than is shown by the figures of Professor Henry.

The German army has probably attained the most scientific methods for feeding, and with them it is universal practise to reduce their roughage to meal and mix with syrup for feed.

Experiments have been made and the fact has been established that draft and work horses can perform the hardest kind of work where their grain has been replaced by molasses, pound for pound, when this molasses is mixed with alfalfa or other kinds of roughage.

Large amounts of straw which were formerly burned to get them out of the way, now form at least a part of the necessary roughage in feed.

The addition of syrup to the ration seems to have a stimulating, tonic effect, which acts very favorably on an animal. For example: The milk production of cows is largely increased by the syrup ration, and the appetite of fat steers is improved. The

sugar in the syrup is of great value, because it balances the high protein in the alfalfa.

Grinding and Mixing

The grinding and mixing of feed for small cattle feeders is done in large mills located in the center of the districts which produce the greatest amount of raw material. These mills require from 100 to 350 hp, and are generally operated 20 hours per day from October until May. They have a capacity of four to five tons of mixed feed per hour. A feeder may haul his raw material to the mills and have it ground and mixed at a cost of from $2.00 to $2.50 per ton.

Cattle feeders who feed several hundred or more head of cattle, or 500 or more head of sheep, usually have a small mill located at their feed pens. This mill requires a 20-hp motor; usually a motor used for grinding is also used for pumping irrigation water in the spring and summer.

The cost for power and labor for grinding and mixing a ton of feed is from 45 to 60 cents per ton.

The average grinding outfit consists of an alfalfa cutter with a 20-in. intake, having a capacity of from one to two tons of alfalfa per hour, a 400-gallon syrup tank equipped with electric heaters to warm the syrup enough to make it run in winter, a corn chopper (where corn is used) and a mixer.

Hay is thrown on to the carrier of the machine and is carried to the first set of revolving knives, where it is reduced somewhat; it then passes to another set of knives set more closely than the first set, where the cutting is continued, and then to a perforated drum filled with one-quarter-inch round holes. Within the drum a cylinder churns the hay and grinds it further, and a suction fan removes it through the holes. The hay is carried into the mixer by means of a screw or paddle conveyor. Here the cracked corn is added (where corn is used) and the syrup is added through jets and the several materials now thoroughly mixed are raised by an elevator to a large storage bin built over the driveway, from which the wagons are filled through an opening in the bottom. The mixture is then hauled to the automatic feeders arranged in long rows in the feed pens. These automatic feeders are filled once a day. A steer will eat this ground feed very rapidly, and when he gets his fill will lie down and

chew his cud. He is contented, and contented animals increase very rapidly in weight.

There is absolutely no waste of feed, and each animal can get his fill with very little effort. There is a marked contrast between this feed pen and the one where hay is fed loose and uncut, because in the latter pen the cattle crowd into the racks, the stronger cattle forcing the weak ones back, and it is not an uncommon sight to see a dozen or more dead steers lying around in a pen, killed from eating too much syrup or whole corn.

In the well-regulated feeding pens there is a water-trough filled by means of a small centrifugal pump, which is operated by a small electric motor. This motor is controlled by a float feed-switch which automatically starts and stops the motor, and keeps the trough filled at all times. It can be readily seen that with a well-equipped feed pen, the labor costs have been reduced to a minimum.

A large cattle and sheep feeder in northern Colorado makes the following statement: "It is a demonstrated fact that the cutting and grinding of farm products saves from 25 to 30 per cent of the materials, and the stock is ready for the market in one-third less time. A gain of 30 lbs. in six months' feeding on sheep with loose hay and whole corn is considered good, while the same gain can be easily secured with the ground food in three months' time when 2½ and 3 lbs. of the ration are fed in 24 hours."

A statement of results taken from an actual case of sheep-feeding shows how the feeding works out:

Number of lambs purchased		965
" " " died during feeding		11
		954
Lambs cost 5¼ cents per lb., average 50 lbs.		$2533.10
" sold 8¼ " " " " 84 "		6821.55
Feeding cost—3 months feeding:		
109 tons alfalfa at $8.00	$872.00	
Chopping hay	218.00	
Corn chop, 139,325 lbs. at $1.25 per 100 lbs.	1741.50	
Syrup, 23,663 lbs. at $9.00 per ton	106.20	
Labor	150.00	
		$3087.70

This hay was ground and mixed in a public mill at Berthoud, Colorado.

Cost of lambs	$2533.10
Cost of feeding	3087.70
Selling price of sheep	6821.55
Profit	1196.75

On original investment of $2533.10, or about 50 per cent.

Silage and the Dairy Farm

In connection with the feeding of stock, the use of the silo is very interesting. The advantages of the silo are: First, no loss in the silage from drying out or decomposition; second, one-tenth the storage space for feed.

The average silo is made of concrete and is about 15 ft. in diameter and from 20 to 30 ft. in height, with a capacity of 250 tons of silage.

In the making of corn into silage, the plant is taken from the field and cut at a time when it contains the maximum amount of digestible ingredients, which are preserved in the silo in this manner, giving the dairyman a form of feed easy to handle and the nearest to pasture grass of any food-stuff obtainable. This silage is fed to the cows throughout the year, with the exception of the period when grass in the pasture is abundant. The ensilage cutter is built on the same principle as a lawn mower, and requires about 10 hp to operate it. A blower attachment is used to force the ensilage into the silo. The capacity of this machine averages about five tons per hour, the current consumption, about seven to nine kilowatts.

As a general rule, cattle are kept in the open as much as possible, in order to prevent infection from tuberculosis. However, during the winter months when the snow is deep, it is necessary to put them in sheds and on a farm where electricity is used, an exhaust fan is installed in these sheds and the cattle are supplied with fresh air.

Electric cuffers, or vacuum cattle cleaners, are now in use on many dairy farms. The modern methods of dairy sanitation compel their use. The electric vacuum milking is sanitary, labor-saving and more thorough than hand milking. The milk house is generally equipped with a 5-hp motor belted to a line shaft, to which are connected a small refrigeration plant, a cream separator, a butter churn, a bottle washer, and a grindstone.

The current consumption on an installation of this nature was, in 1911, as follows:

January	87 kw-hr.	July	147 kw-hr.
February	98 "	August	138 "
March	88 "	September ...	264 "
April	109 "	October	185 "
May	138 "	November	63 "
June	156 "	December	78 "

The dairyman estimated that the electric power in the milk house and cattle sheds saved him the price of one man's hire, or about $50 per month. Before securing electric power he had used a gasoline engine and he estimated that the cost of operation and maintenance were double that of electric power.

The House

The cost of a ton of coal on the farm is about $6.00 and the consumption averages a ton a month.

The servant problem is a difficult one and the farmer's wife is often compelled to do all the cooking and housework.

Electric lighting is usually the entering wedge. The farmer has depended upon and been patient with the kerosene lantern for so long that with the introduction of electricity the contrast is so strong that he is easily convinced of the practicability of electric heating and cooking appliances. As a rule, the current-consumption for lighting is higher on the farm than in the city. This is due to the increased burning hours, as the farmer's day begins about three hours earlier than that of the average city customer. The electric washer and the electric iron soon follow the installation of the lighting service.

That cooking by electricity is feasible on the farm is shown by the yearly kw-hr. consumption of an electric range put under test.

The family consisted of man and wife and three children.

	Kw-hrs. Used on the Electric Range
January	130
February	128
March	110
April	153
May	170
June	167
July	103
August	141
September	201
October	200
November	147
December	150

The average cost of electricity per month being $4.55, a saving of about 25 per cent.

Insurance

Electricity for lighting and power purposes on the farm almost entirely eliminates the danger from fire. During the year of 1910 there were approximately 100,000 fires in rural communities which involved a damage of over $100,000,000 worth of property. A large percentage of this loss was due to the use of oil lamps and other dangerous forms of illuminants.

The following statement is made by W. J. Canada, President of the Electrical Engineers of the Fire Underwriters' Association: "The use of electricity for light and power on farm property tends, where the wiring is properly installed, to a considerable reduction of fire hazard from the general use of oils for illumination and power purposes. Where gasoline or acetylene is used for lighting, special permits must be attached to the policies with close limitation of gasoline and the exclusion of all liquid acetylene within buildings. For storage of gasoline in excess of the 10 gallons, 25 cents per $100 of insurance is charged in insurance estimates. For the use of gasoline engines with supply tank inside of building, a charge of at least 50 cents per $100 of insurance is made. Ordinarily no charge would be made where the gasoline supply is entirely outside of building, ignition is by electric spark, and the engine located entirely free from inflammable vapor, no gasoline tank being used in the building. Where electric wiring is properly installed for lighting no charge is made, and no charge will be made for power if wiring is of standard installation and the motor is of the brushless type."

Summary

From the viewpoint of the farmer, the introduction of electricity into farm methods reduces the cost of production of farm products. The chief saving is in labor and the ability to apply scientific and systematic methods to the industry.

From the central-station viewpoint, it means an off-peak load, a high kilowatt-hour current consumption and a satisfied customer.

POWER CONTRACT No.

READINESS TO SERVE RATE

THIS AGREEMENT, Made and entered into this.....day of.....19...., by and between THE NORTHERN COLORADO POWER COMPANY, a corporation of the State of Colorado, hereinafter called "Company," and .....
of ..... hereinafter called "Consumer":

WITNESSETH, That for and in consideration of the mutual covenants and agreements hereinafter contained to be kept and performed by each of the parties hereto, their successors and assigns, it is mutually understood and agreed as follows:

1. DURATION OF CONTRACT. That Company shall deliver electricity to Consumer for power purposes only during the months of January, February, March, April, May, June, July, August, September, October, November and December of each year, and Consumer shall take and pay for such electricity for such purposes for a period of five (5) years from date hereof; and thereafter from year to year until either party hereto gives thirty days' notice in writing to the other of a desire to terminate this contract, at the expiration of which notice this contract shall cease and terminate.

2. POINT OF DELIVERY. That Company shall deliver electricity to Consumer at the following point or points.....
.....
.....
on Consumers' premises described as.....
.....
.....
and such electricity shall be used on said premises only and not elsewhere.

3. CHARACTER OF ELECTRICTY. That all electricity delivered by Company shall be approximately.....volt, three phase, sixty cycle, alternating current.

4. METERS. That all electricity delivered by Company shall be measured in kilowatt hours by means of a standard make.....volt, three phase integrating watt meter or meters to be supplied, installed and maintained at the expense of.....at the point or points of delivery hereinabove specified in Section Two (2).

5. RATE. That all electricity delivered hereunder shall be paid for by Consumer at the following schedule of rates:

A. A kilowatt hour charge as follows:

For the First 2,000 kilowatt hours delivered per month, at 3.00 cents per kilowatt hour.
For the next 2,000 kilowatt hours delivered per month, at 2.75 cents per kilowatt hour.
For the next 5,000 kilowatt hours delivered per month, at 2.50 cents per kilowatt hour.
For the next 5,000 kilowatt hours delivered per month, at 2.25 cents per kilowatt hour.
For all over 14,000 kilowatt hours delivered per month, at 2.00 cents per kilowatt hour.

B. In addition thereto a net readiness to serve charge per month during January, February, March, April, May, June, July, August, September, October, November and December as follows:

$1.00 per connected horse power for each of first 15 horse power connected
$0.75 per connected horse power for each of next 10 horse power connected
$0.50 per connected horse power for each of next 25 horse power connected
$0.25 per connected horse power for each horse power exceeding 50 horse power connected.

6. DISCOUNT. That Consumer shall pay all bills monthly on or before the expiration of the month following that in which the electricity shall have been delivered. If such bills are paid on or before the tenth (10th) day of the month following that in which the electricity shall have been delivered a discount of ten (10) per cent on the kilowatt hour charge shall be allowed by Company.

7. EQUIPMENT. That Consumer shall at his own expense install a motor or motors of.....horse power capacity, together with all necessary transformers, switches, wiring, overload and low-voltage releases, and all other equipment necessary for utilizing the electricity from the point or points of delivery as hereinabove specified in Section Two (2). Consumer shall also maintain and keep the same in good operating condition.

8. ANNUAL MINIMUM. That in consideration of the construction by the Company of pole and transmission lines and other equipment necessary to provide the service herein contemplated, Consumer shall, anything herein to the contrary notwithstanding, pay to Company a minimum amount of.....
.....Dollars ($.....)
per year for each of the five years covered by this contract, aggregating for the whole five-year period covered by this contract.....
.....Dollars ($.....)
which sum shall be payable whether electricity be delivered or not. Any difference between the yearly aggregate monthly charges payable under Section Five (5) and the guaranteed yearly minimum payment provided for in this Section Eight (8 shall be paid by Consumer to Company not later than.....
.....in each year covered by this contract.

As an alternative to this Section Eight (8) Consumer may, at the time of signing this contract, elect to be governed by Section Nine (9) hereof. In either case the section not adopted by Consumer shall be null and of no effect.

9. CONSUMER TO ADVANCE CONSTRUCTION COST. That Consumer shall pay to Company the entire cost incurred by Company in constructing the pole line, stringing wires, supplying apparatus and equipment necessary to properly deliver electricity to Consumer at the point or points hereinabove specified in Section Two (2) upon the terms and conditions following:

A. The sum of.....Dollars ($.....)
shall be paid to the Company before work is commenced.

B. The balance of the entire cost shall be paid to Company as soon as the construction work is completed and ready for service.

C. Company shall rebate to Consumer.....per cent of the net amount of each monthly bill for electricity presented to Consumer by Company until such time as the entire amount of money paid by Consumer to Company as per paragraphs (A) and (B) of this Section Nine (9) has been rebated to Consumer, after which time this Section Nine (9) shall become null and void.

10. RIGHT OF WAY. Consumer hereby grants to Company an easement over, through and across the premises of Consumer for the purpose of erecting and maintaining pole and transmission lines to supply the service herein provided for, and also for the purpose of serving any other Consumer who may be served from such lines, with the right, at any time, to enter upon said premises and make alterations or repairs thereto; and Consumer agrees that all poles, wires, apparatus and equipment of said pole and transmission lines is and shall be and remain the sole property of Company, with the right and privilege for a reasonable time after the termination of this contract by expiration or otherwise, and of any contract with any other Consumer being served from such lines, to enter upon Consumer's premises and remove all poles, wires, apparatus and equipment used in the construction and maintenance of said pole and transmission lines.

11. HOURS OF SERVICE. That Consumer shall not operate his motor or motors between the hours of 5 P. M. and 10 P. M. during....., except in the case of absolute necessity for the preservation of life or property.

12. CONTINUITY OF SERVICE. Company shall use reasonable diligence to keep the service herein provided for continuous during the months specified in Section One (1) hereof, but shall not be liable for any interruption in said service from any cause.

13. DAMAGES. Consumer hereby agrees to be liable for and indemnify Company against any and all damages which may result from injuries to persons or damage to property of whatever nature occuring on his property caused by the act or omission of either party hereto, or which may be due to the existence, construction, maintenance or operation of the pole or transmission line herein provided for or any machinery, apparatus or equipment of Consumer.

14. FORFEITURE OF CONTRACT. That if either party hereto shall fail for any reason promptly to comply with any of the terms of this contract, or if Consumer shall make default in any of the payments to be made hereunder, this contract may at the election of the opposite party be terminated forthwith against the defaulting party; *provided,* no such termination shall relieve Consumer from the

payment of any amount due Company hereunder, or to become due under Section Eight (8); and, *provided further*, that any failure of Company to deliver electricity hereunder for a reasonable period shall give Consumer no right to cancel this contract.

15. APPROVAL. This contract shall be binding upon Company only after approval by its General Manager.

IN WITNESS WHEREOF, The parties hereto have signed this contract the day and year first above written.

THE NORTHERN COLORADO POWER COMPANY,

By.....

.....

APPROVED: CONSUMER.

THE NORTHERN COLORADO POWER COMPANY,

.....

GENERAL MANAGER.

FOR VALUE RECEIVED, I hereby guarantee the performance of this contract by Consumer in all respects.

.....

GUARANTOR.

....., 19....

POWER CONTRACT No. ....

STRAIGHT METER RATE

THIS AGREEMENT, Made and entered into this.....day of.....19...., by and between THE NORTHERN COLORADO POWER COMPANY, a corporation of the State of Colorado, hereinafter called "Company," and ..... of ..... hereinafter called "Consumer":

WITNESSETH, That for and in consideration of the mutual covenants and agreements hereinafter contained to be kept and performed by each of the parties hereto, their successors and assigns, it is mutually understood and agreed as follows:

1. DURATION OF CONTRACT. That Company shall deliver electricity to Consumer for power purposes only during the months of January, February, March, April, May, June, July, August, September, October, November and December of each year, and Consumer shall take and pay for such electricity for such purposes for a period of five (5) years from date hereof; and thereafter from year to year until either party hereto gives thirty days' notice in writing to the other of a desire to terminate this contract, at the expiration of which notice this contract shall cease and terminate.

2. POINT OF DELIVERY. That Company shall deliver electricity to Consumer at the following point or points.....
.....
.....
on Consumers' premises described as.....
.....
.....
and such electricity shall be used on said premises only and not elsewhere.

3. CHARACTER OF ELECTRICTY. That all electricity delivered by Company shall be approximately.....volt, three phase, sixty cycle, alternating current.

4. METERS. That all electricity delivered by Company shall be measured in kilowatt hours by means of a standard make.....volt, three phase integrating watt meter or meters to be supplied, installed and maintained at the expense of.....at the point or points of delivery hereinabove specified in Section Two (2).

5. RATE. That all electricity delivered hereunder shall be paid for by Consumer at the following schedule of rates:

A—A minimum charge per month of $1.00 per connected horse power or its equivalent.

B—A kilowatt hour charge as follows:

For any portion of
The first 500 kilowatt hours delivered per month, at 5.00 cents per kilowatt hour.
The next 500 kilowatt hours delivered per month, at 4.50 cents per kilowatt hour.
The next 1,000 kilowatt hours delivered per month, at 4.00 cents per kilowatt hour.
The next 3,000 kilowatt hours delivered per month, at 3.50 cents per kilowatt hour.
Over 5,000 kilowatt hours delivered per month, at 3.00 cents per kilowatt hour.

6. DISCOUNT. That Consumer shall pay all bills monthly on or before the expiration of the month following that in which the electricity shall have been

delivered. If such bills are paid on or before the tenth (10th) day of the month following that in which the electricity shall have been delivered a discount of ten (10) per cent on the kilowatt hour charge shall be allowed by Company.

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As an alternative to this Section Eight (8) Consumer may, at the time of signing this contract, elect to be governed by Section Nine (9) hereof. In either case the section not adopted by Consumer shall be null and of no effect.

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13. DAMAGES. Consumer hereby agrees to be liable for and indemnify Company against any and all damages which may result from injuries to persons or damage to property of whatever nature occuring on his property caused by the act or omission of either party hereto, or which may be due to the existence, construction, maintenance or operation of the pole or transmission line herein provided for or any machinery, apparatus or equipment of Consumer.

14. FORFEITURE OF CONTRACT. That if either party hereto shall fail for any reason promptly to comply with any of the terms of this contract, or if Consumer shall make default in any of the payments to be made hereunder, this contract may at the election of the opposite party be terminated forthwith against the defaulting party; *provided*, no such termination shall relieve Consumer from the

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THE NORTHERN COLORADO POWER COMPANY.

By.....

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APPROVED: CONSUMER.

THE NORTHERN COLORADO POWER COMPANY,

.....

GENERAL MANAGER.

FOR VALUE RECEIVED, I hereby guarantee the performance of this contract by Consumer in all respects.

.....

GUARANTOR.

....., 19....

DISCUSSION

MR. J. H. DONLAN, Brooklyn: I jotted down a few points upon which I would like to have some information, but to-night's lesson was my first lesson in farming and if the questions appear to be elementary, I would like to have that fact overlooked. How does this investment of $7.50 per acre compare with the government charges or the charges of corporate irrigation enterprises? What would be the estimated revenues on kilowatt consumption for a farm of 160 acres? Has the company considered the feasibility and possible advantage of grouping a number of these farms together in supplying them, for the purpose of reducing the investment of each farm? Lastly, in these wide stretches of dry land and undeveloped farm lands, what is it that serves to illustrate to the company the possibility of a well or the location of water?

THE CHAIRMAN: We will follow the usual rule and have the questions noted by Mr. Hahn and answered at the end of the discussion.

Mr. H. L. Wallau, Cleveland: In the pictures thrown upon the screen, if I understood correctly, the load curves represented an average irrigation load and a winter peak curve. Before I proceed further I would like to be assured that I understood it correctly.

The Chairman: That is correct.

Mr. Wallau: If this be so, we have been told that this irrigation load is an off-peak load. I cannot believe it. It is not off peak for that station. It requires more capacity than the winter maximum.

The Chairman: You misread the curve. The peak is higher on the winter load.

Mr. Wallau: Then I stand corrected. The point I wanted to bring out was that a load is not necessarily off peak because it is off the winter peak. Most stations have winter peak loads and other loads that are now off peak, but as these loads grow they will have a tendency to change the season of the peak. We have such a condition practically in one of the cities in which our company operates. I think it is the Brooklyn Edison Company whose summer peak, due to the Coney Island service, is greater than the winter peak. For that reason I wanted to make sure whether or not this irrigation load was lower than the winter peak.

Mr. C. W. PenDell, Chicago, Ill.: In the paper mention is made of the use of 2300-volt motors. I would like to ask if there are any restrictions placed on the motor as to size? In what way are the portable motors used where transformers are installed in different places? I would like to ask, too, about the minimum bill, whether there is any stated clause on the minimum bill in the contract?

Mr. John A. Britton, San Francisco, Cal.: I have been intensely interested in the paper and it has brought me a great many fresh ideas on the line of getting new business for the Pacific Gas and Electric Company, although we are doing a tremendous work at the present time in irrigation. Following the remarks made by Mr. Freeman this morning regarding the load-factor of central stations, it may be interesting to you to know that by developing our system of irrigation and reclamation loads in California, we have built up a Pacific system, having a peak last winter of 105,000 kilowatts, or a load-factor of 72

per cent. The load-factor of San Francisco alone averages 55 per cent. This was done by the development of power used within the city. We are not satisfied there to see smoke rising from the chimneys or to hear the puff of gasoline engines. [Laughter.] In California at the present time, in the northern part of the State, north of the San Joaquin Valley, clear up to Red Bluff, there are approximately fifteen million acres of land needing irrigation and we are trying to capture as much of that land as we can. A campaign was introduced about three years ago looking to the use of power for irrigation purposes and at the present time we have installed 25,000 hp in motors used solely for this purpose. Our load, as Mr. Williams' paper describes, lasts approximately for five months of the year. We find by comparison that the ordinary revenue from the city will average $30 per customer per annum. Our average income in a rural district will average $105 per customer per annum. We have also in connection with our irrigation pumping a gravity system. In Placer County we irrigate from reservoirs during the same period of time, five months in the year, something over 17,000 acres of land where fruit exclusively is raised and very little alfalfa. An inch of water will irrigate the land to the extent of five acres to the inch and there is used for the irrigation of those 17,000 acres of land about seventy-two million gallons of water a day. An approximation of that quantity of water may be formed in your minds if I tell you that the city of San Francisco to-day uses only thirty-five million gallons of water a day. More than twice the amount of water necessary for that great city is used daily by the gravity system for the irrigation of Placer County. Our records show a loss from the reservoirs not as great as is disclosed by Mr. Williams' paper, perhaps because we are using ditches older than those in Colorado. The ditches that we use were built all the way from 1850 down to last year, and the loss of water averages just about 50 per cent. In other words, the water measured at the outlet of the dam or at the weir shows that it takes to deliver at the middle of the system about two inches of water for every inch from which we derive revenue. I believe irrigation in the farming districts to be the salvation of central stations in the increase of load-factor and the increase of revenue In the territories where we do irrigation and reclamation work, which

is of the same character, the peak is greater in the summer than in the winter, and for the development of irrigation in our State, as in every other State dealing with water, no additional installation of power or line equipment is required. What we have is sufficient to take care of it.

We seek the farmer in automobiles as the picture shows they do in Colorado; we teach him all we know and all that we can learn; and we are helped by the Government in this respect. Our University of California has specialized in soil culture and development and we take samples of soil to the laboratory of the University and demonstrate to the farmer what can be raised best upon his soil. The University sends through the State during about six months of each year a train supplied by the Southern Pacific Railroad Company, consisting of Pullman cars for the accommodation of those connected with the exhibition which the train carries and the cars equipped by the University of California with all the laboratory matter relating to the treatment of soil; and we have ourselves equipped a car with machinery illustrating the use of electricity on the farm. That train goes through California from Red Bluff down to the Imperial Valley in southern California and education is handed out along the lines by a trained corps of men. In the Sacramento Valley the Northern Electric Railway Company equipped a car for our special benefit, labeling it with our name. This car is a well-known sight in the valley. The results obtained from all this are amazing.

Our rates for irrigation are, I think, as low as those offered by any company in the world. We derive, as the Colorado people do, probably $10 per horse-power per year. That seems very low where we are used to getting $150, $200 or even $500 per horsepower. Our rates run from three cents per kilowatt-hour on meter measurement to a cent and a half, and a bill that would average $150 a month will get the one and one-half cent rate. Thousands of acres of land around Dixon have in the last few years been developed into an amazing farming district. Of course, being watered by the Sacramento River, water is obtained from a depth of from 10 to 12 or 14 feet, but even in other districts where the lift is 50 to 60 feet, and we have that much lift around Woodland, they still find it economical. And the development of the land in any section of country can be made

fruitful by the same means. We distribute literature giving descriptions of pumps, wells, and so forth. We put advertisements in the daily papers, we get literature from the different manufacturing companies and we flood the country with booklets describing what electricity can do for the farmer. We do not charge for line construction at the present time. We have, within the past seven or eight months, developed in the Santa Clara Valley 8000 hp in motors. There is a valley which is the most fruitful in the world. There is where more fruit is raised than in any other given area in the United States. It is only recently farmers have discovered that by the use of water they can produce larger crops, and we are keeping that point before them. I would recommend to you this getting nearer to the soil, so to speak, not to the plough, exactly, as our friend in the picture did, unless you can run a straighter furrow than he, but close to the farmer to show him what you can do for him. [Applause.]

Mr. Samuel Insull, Chicago: I think the pictures that were shown this evening are of tremendous interest, especially to companies between the Alleghany Mountains and the Missouri River. I have been of the opinion for a long time past, in studying the proposition on my own farms, that one of the most neglected industries in the central west is farming. Most farmers find the larger part of their troubles in lack of labor. The gasoline engine is a curse to them. [Laughter.] I am speaking now from personal experience, and I think the greatest lesson we can learn from the gentlemen engaged in creating load for their stations in the arid or semi-arid districts of the west is the possibility of applying the same methods and apparatus to the central-station business of such States as Illinois, Wisconsin, Missouri and Iowa. I know from my own experience that the farming load comes at a time of year when all of you have a lot of capital laying idle, and one of the best things we shall learn by coming to the Pacific coast for our convention is a means of employing this capital during the summer months, and the lesson need not be limited to central station companies lacking in load, especially, or to those that have a superabundance of power running over the dam. We have got to get out and teach the farmers how to use our product. It is a business that will give us in the central west relatively as good

a load-factor as it gives on the Pacific coast. I know of one case just outside Chicago where a truck farmer who had been using the water of the Desplaines River to irrigate his farm was enabled by irrigating to put his crop on the market so much earlier than his neighbors that it paid him to buy energy. It is from lessons of that kind that we learn, and if we will study the operations of the generating companies on this coast, all the way from Los Angeles up, producing energy from steam or from hydro-electric plants, and see the various methods of installation, we can take ideas home to our people and apply them there. Take the small central station in a small city surrounded by rich farming country. The hundreds of uses to which the generating capacity can be put are manifest, and I think if you will study the situation, you will be repaid for the effort. [Applause.]

Mr. J. E. Davidson, Portland, Ore.: We operate in the Yakima Valley largely, the Yakima and Columbia Valley, in irrigation work, pumping about 400 miles and using 66,000 and 22,000-volt transmission lines. In that part of the country the annual rainfall is 6.2 inches and the land is of course of no use whatever without water. We have some 250 plants ranging in size from 2 to 9 hp and we sell electricity on both the meter and flat-rate basis. Our flat-rate charge from April 1 to October 1 runs from $30 to $42 per horse-power season. We sell on a meter basis on a fixed charge of $12 per hp per year and on a sliding scale from 3.5 cents per kw-hr. We find that this has brought up wonderful revenues per capita. We have places bringing us $20 to $30 per capita per year. The average is probably a little over $10. I have some questions I would like to ask the gentleman who read the paper. First, whether they furnish power for irrigation in fruit raising; second, whether or not the power company installs the plant itself; third, have they had any success in using vertical motors and if so, in what manner are they installed. In placing any sort of motor or pump, is the pump of stock make or one designed to meet the conditions at hand? I would like to know also, in the installing of centrifugal pumps, what are the maximum speeds at which they are operated?

(Mr. Blood resumed the Chair.)

Mr. Doherty: I cannot resist the opportunity to illustrate some of the problems that confront us and I hope that the transmission section may have a large part in the solution of those problems. Many of our hydro-electro developments are strictly hydro-electric property, but if they were developed in connection with irrigation, that is with water to be used for both power and irrigation, it would make a great many more installations possible. Not only that, but we have many hydro-electric propositions in this country which lack a market, and irrigation by furnishing this market would add to the profit of the plant. It may seem like a far cry from central-station business to irrigation business as the latter is considered by some a risky business, while the central-station business has come to a point where it is regarded as one of the safest we have, but I think I can venture to say that many central-station plants will find themselves in that business before long. I did not know until to-night that the Pacific Gas and Electric Company was in that business.

I also have a question to ask as to the efficiency to be got from these pumping plants at various depths. One of my friends complains that he cannot get information from engineers. His question is this: "From what depth can I afford to pump water for irrigation purposes?" [Laughter.] I told him there were a lot of questions for him to answer first, the value of the land, the crops to be raised and conditions generally, before anyone could tell him how far he could pump the water. When I learned that he was raising Bermuda onions at about $600 per acre, I figured that he could pump water practically from the bowels of the earth. [Laughter.] Certainly the 30 to 60 foot well of which our friend speaks is not the limit if crops are of sufficient value. Sometimes in New York City I feel like talking about what is done in Colorado and in the west, but I am afraid to because my reputation is not sufficient for me to tell the truth about it. Out here, however, it can be done safely. In reality, then, crops to the value of $3,000 on a single acre and many fruit lands from $700 to $1,000 an acre are not unknown. Many of us who live in New York City and get our opinion of farm lands from what can be produced in that locality do not realize the possibilities which the farm offers to the promoters of electric enterprises. Recently a problem in hydro-electric work came up in our office and we found that the

ground was made for irrigation work. At the prevailing rate for water it would give the equivalent of $5.00 per acre-foot of water, while for power purposes it was worth only $0.48; the water was worth nearly ten times more for irrigation than it was for power. A valley alongside of a great river with thousands of acres of land at an elevation too high to be supplied by water on a gravity system and yet an abundance of water and an abundance of very excellent land for agricultural purposes, is what the traveler sees from end to end of this country. I would like to have an estimate of the amount of land so situated. I think it would be a surprise to all of us.

One speaker has tried to make the point that as we develop the intervention load it will finally become the peak. It simply means going out further and hitching another station to it. That is the reason why the central station has continued to grow from a geographic center. That is why it is advisable to cover a number of different kinds of business and large territory. Rivers such as some that we passed over in coming out here run down to the sea. Our people do not seem to realize that just that much wealth is being washed away. They complain about the rapidity with which some men accumulate riches when there is plenty of opportunity still for others to do it. If they have the proper organization and can raise the capital to create the enterprise, they, too, can do it. There are more enterprises awaiting development to-day than men of ability to handle them.

Mr. D. F. McGee, Portland, Ore.: I would like to ask if any members have used single-phase motors for irrigation pumping and also if any of the companies have developed a rotary system of supply, that is, unity of interest, where various customers get together and contract for a certain amount of power to be used by each, one day in the week.

Mr. Peter Junkersfeld, Chicago: I would like to ask some questions of Mr. Britton. First, as to the load-factor of 72 per cent, is that annual or monthly?

Mr. Britton: It is annually.

Mr. Junkersfeld: What proportion of the total consumption that load-factor was based on was used in municipalities, and what in the farming district? I would like to ask Mr. Williams, in the case of our friend John Redmond and the fields of small grain, how much of an area it is profitable to irrigate from a central well, say 50 or 60 feet deep?

Mr. John C. Hays, Visalia, Cal.: The Mt. Whitney Power Company of California was one of the first companies to go into the irrigation game. We started in 1899 with true California spirit to install a power plant and then look around for some load. The perspective showed about 100 hp available, and as we had to get business, and at that time there was some talk of growing oranges, we turned to irrigation. The company has been and is an almost exclusively irrigation company; our load-factor depends almost entirely upon irrigation. The other day we had occasion to go over the figures and found that 90 per cent of the total output was used for pumping water. The peak loads in winter would run up to possibly 70 per cent as high as in the summer-time, but they were lighting loads and short peaks; so that 90 per cent of the current generated during the year was used for pumping water. The load-factor was about 45 to 55 per cent and is probably constant from year to year. The matter of development was determined at the outset to cover a certain territory. We took Tulare County and went to almost any extreme to put a line through a good section. The average rule in the office was a mile to 6 horse-power. It was entirely a development proposition. We have been at it since 1899 and we are just starting. Looked at in one way it is slow work, a matter of waiting for dividends, but the increase is very rapid, being about 25 per cent a year. The charges are based on a flat rate and we have a meter rate which amounts to about the same thing, but the average farmer likes to know how much it is costing him, and, at the start, we established a rate, rather guessing at it, of $50 per horse-power per year on the maximum demand. This is for any size of motor. The little farmer receives more encouragement than the big one and comes in on an equal basis. The people who build up that kind of territory generally do it on 10, 20 and 40 acres and our rate is divided up that way. We have a strictly peddling business, the average size of the motors being 7½ hp.

As to the height for lifting water to irrigate alfalfa, in one part of the district the wells will almost flow and then we have one plant in the orange groves where the lift is 460 feet. The general idea is, I think it is mostly superstition, that to get on the west slope of a hill is better for oranges, freer from frost, and they all get close to the hills. The 460-foot plant is the

highest but the land is not very good; it has washed down. The average lift in the orange district is about 80 feet, but there are several of 200 and 300 feet. They generally pump the water to about 70 feet from the well and then relay it up the hill. The matter of evaporation and wastage of gravity water is something that it is practically impossible to get any reliable data on. I know, in the case of the Turlock irrigation district, that when they started in the water at the headgate amounted to 30 feet on the land irrigated, but it is now down to three feet. The tendency of the farmer is to run too much water on. The rainfall in our district is about 10 inches.

As to the orange industry, it is very profitable. In the section where we are operating the land is worth about $400 an acre near the towns. It was worth in years gone by about $25 an acre. I do not suppose there is land anywhere at less than $150 per acre. The average yield from an orange grove is about $250 an acre net. The average power used per acre, taking the old system, is about one horse-power on the $50 rate, for the 5 acres. The gasoline engine is not altogether the curse we would like to have it, but we find that the farmer does not have time to attend to it. There are a great many gas engines that run right along and we cannot get them off the system. Gas engines are a very serious competitor. As to the peak load, our peak is in July and August, and it seems to run from ten o'clock in the morning to one or two o'clock in the afternoon. All of the towns are extremely small and the receipts from a rural community for lighting are very low. The farmer goes to bed earlier than the city man.

Mr. H. R. Kingman, Portland, Ore.: Just one or two points. First in connection with the power on the farm other than for irrigation: We started out by recommending continuous-connected motors and centrifugal pumps, but found it impracticable to take a farm motor off the bed plate and cart it around. We are now recommending belt-driven outfits, although the efficiency is not quite as high. The farmer has his motor available for other purposes, however.

As the gentleman from California just now stated, orange land is valued at perhaps $400 to $500 an acre, while the Yakima Valley apple lands run from $3,000 to $4,000 an acre. You can pump water a long ways for crops of that valuation. It makes

a great difference what you are pumping for. We are pumping on lifts of 150 to 200 feet.

Another point. We have several customers who could pump from ditches but are pumping from wells. In our valley the average temperature of the water coming from the wells is 70 to 75 degrees. You can see what it means to take water at a temperature like that and put it on the land in the spring. It will develop crops 30 days sooner than cold ditch water from the mountains.

Some of you were amused at the screen picture showing the blowing up of a gasoline engine just as the agent appeared on the scene, but this is not a joke. It is an actual fact that it has happened twice to my knowledge. [Laughter.]

Mr. R. H. Ballard, Los Angeles, Cal.: I have been greatly impressed in these meetings by the information imparted showing great advantage to be gained by us, while Mr. Doherty, of New York, did not know that Mr. Britton was in the irrigating business, and we have been sitting around Los Angeles thinking that we were the real thing in this matter of pumping water for irrigation plants! We have 25,000 hp and the effect on our load is marvelous compared with other sections, although we have not developed such a load-factor as Mr. Britton has. Down in southern California the income per horse-power on installed capacity is greater than in the northern parts of our State. I think that is probably due to the extra amount of water used on the orange lands. Reference has been made to an income of approximately $10 per horse-power. In southern California, the income is nearly $20 per horse-power. We also do some talking about gasoline engines. We have had about one hundred of these engines break down and get rid of themselves. We have bought about a hundred more. We took these and shipped them to Arizona or some other distant point, as far from our lines as possible, but we also sold some of them to customers along our own lines. I will say in explanation of this, however, that we have sold them where we had been working for a long time and saw no chance to get in an electric motor. Now all you have to do with a difficult prospect is to sell him a gasoline engine and wait for it to break down. [Laughter and applause.]

Mr. H. S. Wells, Portland, Ore.: I would like to state that on the Columbia River we have one difficult condition.

The pumping head varies from 17 to 20 feet and we have found that it develops less efficiency at one extreme or the other. I am wondering what experience other companies have had under these conditions.

THE CHAIRMAN: I shall call upon Mr. Hahn to close the discussion and answer the many questions asked.

MR. HAHN: In reply to the first question—How does this investment of $7.50 compare with the government charges, or to charges of corporate irrigation companies?—I will say that the actual cost of ditch and reservoir water in the year 1911 averaged about $50 per acre. The Government enterprises are estimated to cost from $35 to $60 per acre for gravity systems. Dr. Fortier, Chief of the Irrigation Bureau, says that the price of water will never be less than it was in 1911.

Government engineers recently sank a well of the casing type on the experimental farm near Cheyenne, Wyo., and the cost of this well and pumping plant complete was about $10.50 per acre. Within the past few years many farmers of northern Colorado have disposed of their gravity water rights and have sunk wells and installed pumping plants on their farms. Taking a general average, I believe it is safe to say that the farmer makes a saving of $40 per acre on his investment by the installation of a pumping plant.

What would be the estimated revenues on the kilowatt consumption for a farm of 160 acres?

The average of a large number of plants in northern Colorado shows the average height to which water was pumped to be about 23 feet, and the cost of current, $1.40 per acre, charging 3 cents per kw-hr. and pumping an acre-foot of water on the land.

Has the company considered the feasibility and advantages of associating a number of farms together for reducing the investment?

In a few instances we have succeeded in getting several farmers to go together in the installation of a system, but as a rule we find the farmer an independent individual. Our one great talking point with him is that the pumping plant will make him independent; that with it he may pump water on his land when his own crop needs water, and not have to wait until all of his neighbors are ready. He knows that even a small degree

of drought will start his crop upon a maturing process. If moisture is added later, instead of promoting the old growth an undesirable new growth is added. Thus you see the advantage of every farmer owning and operating a separate plant.

I am asked what serves to illustrate to the company the possibility of a well or the location of water.

The territory through which the lines of the Northern Colorado Power Company run lies from 10 to 25 miles from the foothills of the Rockies. It is a fact that only 50 per cent of the precipitation in the mountains runs down the mountain streams; the other 50 per cent sinks beneath the surface and gradually finds its way through the sand and gravel, unless intercepted, to the rivers on the plains. This underflow in northern Colorado is found about 25 feet below the surface and is located by means of test holes. There are very few localities in our territory where we cannot strike the underflow.

In regard to the load curve which was shown upon the screen, I would like to say that when Mr. Williams took charge of the company five years ago, we had no day load and a peak in August was never dreamed of. He has developed the pumping business to such an extent that the kilowatt-hour output is greater in the summer months than in the winter, although the demand is much larger in the winter. The kilowatt-hour output for 24 hours of a day in August is greater than the 24-hour output of our highest peak in December.

Are there any restrictions placed on the installation of 2300-volt motors as to size? We do not place any restrictions upon the installation of primary motors. Fifteen horse-power is the smallest 2300-volt motor connected on the line at present. Where the farmer purchases motor and transformers, the 2300-volt motor is the cheapest to install. We have had most satisfactory results with these motors.

Where a portable plant is used and transformers are installed in different places, what is the minimum bill?

Where a portable plant is installed the farmer generally builds all secondary distribution lines, buys all the transformers necessary and is charged on the connected load only. The current is sold at 2300 volts, and as the customer stands the core losses he never fails to cut off any transformers not in use. For example, in case of a 10-hp motor on a portable plant,

the readiness-to-serve charge would be $10 per month regardless of the number of pumping stations.

Does the company furnish power for fruit irrigation? Yes, large orchards of cherries, apples, peaches and many hundreds of acres of berries are irrigated by electrically driven pumping plants. These installations bring in better returns to the company, as more water is used for fruit irrigation than for grain or alfalfa.

Does your company install the plant? At present we do not go into the installation of pumping plants, but advise the farmer as to the kind of pump and motor, size, etc., needed, and stand ready to see that his installation is properly placed. Our company is considering the organization of a department to sink wells and install a complete plant. Our plan is to go to a farmer and guarantee to sink a well to deliver a certain quantity of water or to make no charge. In other words, we will stand the loss where no water is secured. Where the cost of a casing well runs about $2.50 a foot, the farmer is rather timid in taking a chance. We believe that when we assume the risk and install the wells properly, the pumping business will increase rapidly.

Regarding the installation of vertical motors, I recall but one such installation on our irrigation lines. We do not recommend them because we wish to educate the farmer to make many uses of his motor and not confine the use of power to irrigation alone. The regular type of motor he may move about, and make serve many purposes.

The cattle-feeding industry in northern Colorado is destined to develop into as great a factor as our pumping business. We believe that the future of Colorado depends upon the feeding of the hay and roughage that is grown in the State, right there in our own territory. Our soil needs the additional humus which it gets from the fertilizer which is hauled from the feed pens. In the majority of cases the motor which is used for operating the pump during the irrigation season is used for driving hay cutters, corn grinders, etc.

Where a pump is installed, is a stock pump selected or one especially designed for the installation?

The majority of plants require a specially designed pump to meet the various conditions; for example, where a pump must deliver certain quantities of water to different heights, it must

be built especially for these conditions to secure the greatest possible efficiency. For low lifts which do not vary we generally install a stock pump. A pump has recently been designed which delivers water at different heads with very good economy throughout its range.

There is evidently some uncertainty as to the length of the pumping season in Colorado. I will state that it begins during the latter part of May and continues until the latter part of September. The heaviest demands for power come in August, at which time sugar beets, potatoes and alfalfa require heavy irrigation.

I am asked the maximum speed of any pumps in use.

Fifty per cent of the installations in our territory are direct-connected outputs and, as a general rule, we use a motor having a speed of 1120 r. p. m. There are intervals where the pump is speeded up to deliver more water, when the speed is greater than 1120 r. p. m., but the efficiency of the pump is greatly lessened.

What is the efficiency of plants for various depths?

The pump manufacturers claim as high as 72 per cent efficiency for their pumps, but we usually figure it at 50 per cent. The proper installation of a plant has much to do with its efficiency. The speed of the runner and the amount of water both have a direct bearing on its proper working.

There was a question as to how large an area can be irrigated from one well? I believe that the largest tract in our territory irrigated from a well is 360 acres. This well delivers 200 inches of water continuously. It is an open-type well 15 feet in diameter and 30 feet deep. The water rises within 15 feet of the surface and never drops more than 4 feet when the pumping is the heaviest. This is one of the oldest wells in Colorado and delivers more water now than at the time when it was sunk. This is a characteristic feature of all our wells.

In regard to the temperature of the water from the wells, we had a condition in Colorado last year which was just the reverse of that of which the California member spoke. Our potato crops were greatly damaged by a blight and the Agricultural College made a series of experiments to determine the cause. They experimented on the plant by changing its temperature and moisture conditions and found that the blight increased as the temperature of the water increased. The

application of warm water from reservoirs was very disastrous to the potatoes. When the cooler water pumped from wells was run on the land the blight seemed to disappear. The temperature range in which the potato can grow is about 15 degrees, from 70 to 85 degrees F. The well water is at an almost constant temperature and much lower than the reservoir water. Last year, tracts of land irrigated from wells produced 100 sacks of potatoes per acre, and the same kind of land watered from the ditch produced 5 sacks per acre only.

Do we regard the gasoline engine as a strong competitor? We have never purchased a gasoline engine in order to install electric power. We assist the farmer in selling his engine after he has installed the electric drive, but we do not regard the engine as a serious competitor. Our installation, operation and maintenance costs are less than theirs, so I do not see where competition comes in. We do, however, regard the fuel-oil engine as a competitor because of its low operating cost.

What is the smallest primary motor? The 15 hp is the smallest 2300-volt motor on our service.

Does the farmer move his transformers around? Usually the farmer has a set of transformers at each pumping station, which relieves the necessity of calling a man from our office each time he wishes to move the outfit. He can connect the secondary side all right but we could not allow him to tap the 2300-volt line.

Do we make a charge on the irrigation lines? The farmer is offered two propositions. The first is to pay for all line construction necessary to reach his plant. In this event we rebate to him about 50 per cent of his yearly bills until the line has been paid for. We retain the ownership of the lines and keep them in repair.

His alternative is to sign a contract for five years with a guaranteed yearly minimum based on 50 per cent of the construction costs.

What is our fixed charge? We charge one dollar per month per connected horse-power. We allow the customer six months' use of power upon payment of a fixed charge for four months.

(Adjourned.)

SECOND POWER TRANSMISSION SESSION

WEDNESDAY AFTERNOON, JUNE 12

THE CHAIRMAN, MR. HENRY L. DOHERTY: We have received a suggestion that we change the name of the Power Transmission Committee to the Hydro-electric and Transmission Committee. If this change is acceptable to the Section will some one on the floor make the necessary motion?

The motion was put to vote and carried.

THE CHAIRMAN: This, then, is the first meeting of the Hydro-electric and Transmission Section. The Chairman has appointed the following committee on nomination of officers for the following year: Himself (Henry L. Doherty, New York); Mr. John A. Britton and Mr. P. T. Hanscom, San Francisco. This committee is to report at the session Thursday afternoon.

The first paper on the program to-day is "Work and Publications of the United States Government Relating to Hydro-electric Development." The paper is by Mr. J. C. Hoyt, Washington, D. C., and will be read by Mr. Glenn L. Parker.

Before Mr. Parker is formally introduced I want to state the reason why this paper was requested of the Government so that we shall get the greatest benefit from its presentation.

The Government is spending a large sum of money to determine the data necessary for the development of water-power. Much of the work that it does has a direct bearing on the information this Section needs about water-power development. Undoubtedly they could change much of their work, and would be willing to do so, if it were suggested by capital engineers and good reasons given. We are anxious to have the reading of this paper carefully followed and discussed, and any comments, especially along the line of making the work of the Government more valuable to the engineers engaged in hydro-electric work, should be kept in mind.

WORK AND PUBLICATIONS OF THE UNITED STATES GOVERNMENT RELATING TO HYDRO-ELECTRIC DEVELOPMENT

By John C. Hoyt*

Mr. James J. Hill, the famous railway builder, whose lines of steel cover more than eleven thousand miles of our continent, once said, in addressing a group of government engineers: "Next to the Deity, the civil engineer comes nearer to being a creator than do men of any other profession. He wants only a cheerful banker to advance the wherewithal for expenses and he will attack any problem in nature and master every difficulty of construction."

In this striking statement Mr. Hill probably assumes that if the success of the undertaking is to be assured, the engineer would have at command, in addition to the necessary financial resources, a working knowledge of the essential factors entering into the problem which he attacks. Without such a knowledge the economical completion and successful operation of a project is doubtful, for many a failure can be traced directly to errors due to lack of knowledge of the prime conditions on which the success of the project depended.

Every engineer who is required to devise a project of any sort must first procure and consider all available data that may in any way be of value in his proposed work.

In general, the limit of time and funds available for the investigations required for a conclusive engineering report prohibits the engineer from collecting original basic data. He must accept data gathered by others, and on the amount and character of data obtainable and his ability to bring the facts together and analyze them, the value of his report must depend. Definite knowledge of the sources of reliable data is, therefore, essential.

In this connection it may be noted that the work of the investigating engineer must precede and serve as a foundation for all designs and construction. His place is, therefore, as important and should command as much respect as that of the designing and constructing engineer.

* Engineer in charge of Surface Water Investigations United States Geological Survey

The purpose of this paper is to call attention to certain kinds of information of value to those preparing reports relating to the feasibility of the development of hydro-electric power.

In the departments of the National Government there are many technical and scientific bureaus engaged chiefly in studying the resources of the country and indicating the manner in which these resources may best be utilized and developed, and some of these bureaus also carry on construction and development work for the benefit of the people.

Governmental investigations are, of course, conducted impartially, and all sides of the subject under consideration are studied and recorded, information unfavorable to a project being quite as essential and valuable as that which is favorable. Most Governmental investigations can also be carried on more thoroughly and systematically than those of the private investigator, who must satisfy a demand for immediate financial return.

The scientific work of the Government employs a large corps of men who have devoted years to special lines of study with such success that the methods and results of Governmental investigations are now accepted as standard not only in this country but in many foreign countries.

AVAILABLE GOVERNMENT DATA

In reports on hydro-electric projects, three things must be considered and appraised at their proper value: First, the quantity of power available; second, the cost of its development and distribution; third, the available market and the probable returns.

Governmental data of value in connection with such reports may be grouped under six subjects. These subjects and the principal bureaus engaged in investigating them are as follows:

1. Water Supply.
   - Geological Survey.
   - Engineer Corps, U. S. Army.
   - Weather Bureau.
   - Reclamation Service.
   - Special Boards and Commissions.
2. Topography.
   - Geological Survey.
   - Land Office.
   - Engineer Corps, U. S. Army.
   - Forest Service.

Coast and Geodetic Survey.
Special Board and Commissions.

3. Geology.
   Geological Survey.
4. Climate.
   Weather Bureau.
5. Social and Industrial Conditions.
   The Census Bureau.
6. Experimental Engineering Data.
   Bureau of Mines.
   Bureau of Standards.

Data available on each subject can best be indicated by briefly outlining the work of the bureaus making the investigations. The range and magnitude of this work is well illustrated by the monthly lists of the Superintendent of Documents, which show that 16,420 publications were issued during 1911.

Geological Survey

Prior to 1879 no systematic studies of our natural resources had been made by the Federal Government. In that year the Geological Survey was organized under an act which specified its chief function as "the classification of the public lands and the examination of the geological structure, mineral resources and products of the national domain." Working under this broad charter, the Survey collected and combined the results of all previous investigators and adopted a program which has been extended to cover the whole country. In prosecuting the work as defined in the Organic Act, it has been necessary to study many allied subjects, so that data relative to practically all of our natural resources and the conditions affecting them are now available in the Survey.

The Survey's work may be classified under the following heads:

Geologic Surveys and Investigations.
Topographic Mapping.
Mineral Statistics.
Water Resources and Investigations.
Classification of the Public Lands, which utilizes the work of the other branches.

Keeping in close touch with other organizations, both Governmental and private, which are studying the natural resources of the country, the Survey acts to a certain extent as a clearing house for all such information, and if its own records

lack the desired data, it can frequently suggest the source from which they may be obtained.

Reclamation Service

The Reclamation Service, which is primarily a construction bureau, was organized for the specific purpose of reclaiming arid public lands. Its work was made possible by the earlier investigations of the water resources branch of the Geological Survey, and its projects have generally been based on water-supply data collected by that bureau. Its own investigations are necessarily restricted to those factors which relate to particular projects under investigation or construction. Nevertheless, the Service has collected a large amount of valuable data covering all phases of investigation, construction and operation of irrigation development, including power as a necessary part or as a by-product thereof. These valuable data should not be overlooked by those who are interested in projects in the arid land States. The maps and detailed surveys made by the Reclamation Service cover large areas, and its designs of systems and structures exhibit the best practise in many types of engineering construction.

Weather Bureau

From the viewpoint of the engineer, the most valuable data gathered by the Weather Bureau are the precipitation records that have been collected at stations well distributed throughout the country. Many of these records cover long periods, and, in general, they are sufficiently complete to indicate average and extreme conditions. Not only is the summary of precipitation records, recently compiled and published by the Weather Bureau, the most complete report of its kind that is now available, but it includes other climatological data, and, for certain selected stations, determinations of average stream run-off compiled from the records of the Geological Survey. Although records of precipitation can never take the place of records of stream discharge, they are of great value in estimating the probable maximum, mean and minimum discharge of streams in many localities. To be of greatest use, however, such records should be studied in connection with precipitation data collected in basins of streams whose discharge has been recorded for a number of years.

Of special value to the engineer is the work of the Weather

Bureau in predicting floods. The data assembled in connection with this work comprise many series of records of river stage, and include a great number of the longest and most valuable of such records available. Other meteorological data important in engineering investigations, including information in regard to temperature, evaporation, wind velocity, relative humidity and electric storms, are also collected by the Weather Bureau.

General Land Office

The primary function of the General Land Office is the subdivision, administration and disposal of the public lands, and the Land Office maps of the many areas in the public-land States are the only ones that can be obtained. The plats showing the record and status of filings on the public lands in any district are open to inspection in the local land office, and those for the whole country are kept in the General Land Office in Washington. These records must often be consulted by engineers in connection with titles and rights of way.

Coast and Geodetic Survey

The principal work of the Coast and Geodetic Survey is the mapping of the coast line of the country and the study of tidal currents, but this bureau also carries on systematic triangulation and leveling, which will eventually cover the whole United States and serve as a basis for the horizontal and vertical control of all Governmental and other surveys. In performing this work it has assembled and adjusted the results of triangulation and leveling surveys made by other government bureaus, by railroad companies and by private engineers whose work shows the required degree of accuracy.

The magnetic charts of the Coast Survey also serve as a guide in all work involving the use of the magnetic needle.

Forest Service

The work of the Forest Service pertains chiefly to the administration of the national forests, but it has resulted also in the accumulation of a large amount of information which is valuable to the engineer, such as is embodied in maps showing the nature and value of the forest, and in reports on water supply and allied subjects.

Full co-operation with this bureau will greatly facilitate any engineering work in or adjacent to a national forest. The Service publishes regulations in regard to obtaining timber from the national forest, and the procedure necessary in connection with the development of water-power.

It maintains also an experimental department, which makes tests to determine the most economic use of timber.

Corps of Engineers, U. S. Army

The Corps of Engineers has charge of the river and harbor improvements, the Lake Survey, the Missouri River Commission and the Mississippi River Commission, and conducts such special miscellaneous investigations as are assigned to it. In the course of this work it has collected much information in regard to the topography of certain areas, stream flow and water storage, as well as other data of great value to engineers, and it has designed and built many kinds of river and harbor improvements, such as dikes, jetties, storage reservoirs and controlling dams and canalization.

Many reports on the work of the Engineer Corps have been published, and much unpublished information is on file in the Washington office and in the various field offices. A three-volume index covers the reports of the Chief of Engineers from 1886 to 1900.

Special Boards and Commissions

Before appropriating money for any Government project, Congress often requires that its feasibility be considered by a special board or commission, which, for administrative purposes, is ordinarily attached to one of the executive departments. Boards dealing with engineering projects are, as a rule, placed under the War, Interior or State departments. Reports of these boards or commissions are submitted directly to Congress and are usually published as congressional documents.

The following engineering boards are fairly permanent: The Mississippi River Commission and the Missouri River Commission, which work under the Corps of Engineers; the International Boundary Commission, directed by the State Department, which deals with the division of the waters of the Rio Grande and certain other questions at issue between the United States and Mexico, and the International Waterways

Commission, also under the State Department, which deals with questions relating to the international streams of the United States and Canada.

Special mention should also be made of the reports of the National Conservation Commission, which was appointed by President Roosevelt and, in February, 1909, made a special report containing a partial inventory of the natural resources of the United States. This report was compiled from records collected by the Government departments, which performed most of the work of compilation.

The National Waterways Commission, established by Congress in 1909, has just finished a complete investigation of the various phases of development of the water resources of the country. Their report, based upon studies both in this and in foreign countries, will cover (1) the relation of railways to water transportation, (2) the effect of forests on stream flow, (3) the relation of storage reservoirs to flood protection and as an aid to navigation, and (4) the development and control of water powers.

Bureau of the Census

Data in regard to social and industrial conditions in the United States are collected by the Bureau of the Census. Since 1870, statistics in regard to the power used in the operation of manufacturing establishments have formed a part of the statistics on manufactures. In 1902 the scope of these statistics was extended to cover central electric light and power stations, street and electric railways, and telephone and telegraph business, so that a complete census of the manufacturing and electrical industries of the country is now made every fifth year. In addition to the statistics concerning the financial operation, number of persons employed, etc., the census reports contain many details concerning the size and equipment of plants and the character and quantity of power used. The first complete census of the electrical industry was taken for the year 1902, and the second covered the year 1907.

The statistics cover all central electrical and power stations and every electric railway that was in operation during any portion of the respective census years. The relative use of steam, gas and water power as prime motors in such central power

stations was reported. No attempt was made to include statistics for the thousands of isolated electric plants.

The statistics of the Census Bureau are tabulated and published in various forms, in order to present the material collected to the best possible advantage.

Bureau of Mines

The principal function of the Bureau of Mines is the investigation of questions relating to the mining industries of the country. Many tests of various explosives have been made by this bureau, and its special studies in connection with the use of fuels will be of value in the development of auxiliary power stations.

Bureau of Standards

The work of the Bureau of Standards is principally along experimental lines. The bureau is equipped for many kinds of general study, both of materials and instruments, and its data will be of value in connection with the selection of machinery and material.

Other Government Bureaus

In addition to the bureaus which make a specialty of gathering data of value to engineers, there are many others that incidentally collect information with which the engineer should be familiar.

In the Department of Agriculture there are the Bureau of Soils, whose maps show not only the character of the soil but also the topography of the areas studied; the Bureau of Statistics, which gathers a large amount of information showing the industrial development of the country; and the Office of Experiment Stations, which collects much information in regard to drainage, irrigation and other matters of interest to the engineer.

In the Department of Commerce and Labor are the Bureau of Statistics, which collects data that cover all lines of industrial development, and the Bureau of Corporations, which has just completed a report on the economic features of water-power development in the country, covering the demand for power, the amount developed, its ownership and its relation to the public. This bureau has also made an exhaustive report on terminal facilities in connection with water transportation.

The War Department maintains an extensive laboratory at Watertown Arsenal under the Ordnance Office, where tests are made of structural materials for the government.

Data Outside the Federal Government

Attention should be called also to the work of States, municipalities and private organizations which are carrying on investigations similar to those directed by the Federal Government. All the western and many of the eastern States have State engineers, whose functions, among other things, include the administration of the waters of the State. Many States have conservation commissions and geological surveys whose publications are of general value and may be obtained by applying to State officials at the various capitals.

HOW TO OBTAIN GOVERNMENT RECORDS

Government publications are, in general, classed either as Congressional or Departmental documents, and are deposited for distribution as follows:

1. With the document rooms of the Senate and House of Representatives.
2. With the bureau under which the work is carried on.
3. With the Superintendent of Documents.

House and Senate Document Rooms

The document rooms of the Senate and House of Representatives are maintained primarily as the depositories for Congressional records and such other reports as Congress may order printed. They contain, also, some Departmental publications which are issued as Congressional documents. Publications from this stock are distributed only on the order of members of Congress, to whom all applications for Congressional documents should be sent.

Neither the Senate nor House document rooms issues a list of publications in stock. They are, however, listed in the Monthly Catalogue issued by the Superintendent of Documents.

Government Bureaus

Most of the departmental publications deposited with the bureaus in which the work is done are distributed free of charge, but a nominal price is placed on certain issues in order that they may be obtained only by persons who need them and appreciate their value.

Requests for information receive special consideration in all Government bureaus. In applying for data, the applicant should state precisely what he desires, and, in addition, should indicate the use which he hopes to make of the data. The average applicant for Government data expresses his needs so vaguely that he fails to receive much information which could be sent.

Most Government bureaus issue complete indices, bibliographies, index maps and other guides to the results of their work so that those interested can readily ascertain what is available. These reference publications should be included in the files of every engineer.

Owing to the small editions of most publications, it is absolutely impossible to maintain even a small list of those to whom publications are regularly mailed. In place of such a mailing list, nearly all bureaus publish, at more or less regular intervals, lists of publications which are mailed to those interested in the work of the bureau. In general, requests for departmental data should be addressed to the bureau under which the work is done.

Superintendent of Documents

All publications deposited with the Superintendent of Documents are sold, the price fixed being only sufficient to cover the cost of paper, press work, binding and distribution. This nominal price prevents applications from persons who would not use the reports. This office acts as a conservator of papers, and is generally resorted to after other stocks have been exhausted.

The *Monthly Catalogue, United States Public Documents,* issued by the Superintendent of Documents, gives a complete list of all Government reports issued during each month. In this list the publications are classified by the departments under which the work is done. The subscription price for this monthly catalogue is $1.10 a year.

Other lists issued from time to time indicate the publications relating to certain topics or to the work of particular departments or bureaus. The scope of these catalogues is illustrated by the following lists, which are of special interest to the engineer:

List No. 18.—Engineering: Mechanics. List of United States Government publications relating to electricity,

fuel testing, structural materials, manufactures, river and harbor improvements, etc.

List No. 20—Lands. United States public documents relating to lands, irrigation and reclamation, conservation, forests, etc.

List No. 43—Forest Service publications.

List No. 48—Publications of the Weather Bureau and of the Signal Office.

List No. 53—Maps published by the United States Government.

Information concerning the titles of the various lists may be obtained by applying to the Superintendent of Documents, Washington, D. C.

WHERE GOVERNMENT RECORDS MAY BE CONSULTED

Practically all Government publications are issued in small editions and can be supplied to comparatively few individuals. Great demand for some of them soon exhausts the supply. In order to make them generally accessible, copies are deposited in certain public libraries that have been designated as Government depositories. Some of these libraries receive all Government publications; others receive only papers relating to special subjects.

Another important source of information concerning Government work and publications is found in the local offices maintained by the Weather Bureau, the Geological Survey, the Reclamation Service, Corps of Engineers, the Land Office, the Forest Service, the Coast and Geodetic Survey and other bureaus. A local office generally has a fairly complete file of all publications of its own bureau and may also have those of other bureaus.

As a rule, these offices are located in the Federal buildings of principal cities, but their location can readily be found in the local city or telephone directory.

In addition to the published data, there are many manuscript records available for consultation either in the Washington office or in the local offices of the various bureaus. In general, no lists or indexes to these data are published, and they can be obtained only by applying to the various departments and stating clearly the information desired.

(During the reading of the foregoing paper the Honorable Richard A. Ballinger, ex-Secretary of the Interior, entered the convention hall and was escorted to his seat on the platform, amid cheers and applause.)

Mr. Parker (continuing): I would like to say that Mr. Hoyt had prepared in Washington a list of catalogues and a few of the publications named, to show the nature of the report and has sent them here as an exhibit, and I shall be very glad to answer any questions that may be asked regarding the issue of the catalogues and the person to whom communications should be addressed in case publications are wanted.

DISCUSSION

Mr. Jacobs, Seattle: The thoughts that have come to me in listening to the reading of Mr. Hoyt's paper I have set down only this morning. I have had no time to review or even to typewrite my remarks and I therefore beg indulgence for their crudeness.

Mr. Hoyt's paper is valuable in that it brings to our attention the fact that the Government has entered in a very comprehensive way into the study of our physical resources, and that the results of its investigations are being compiled in convenient form for ready reference of both the layman and the engineer. This work has been in progress for many years, and it is surprising therefore that so few engineers are really familiar with the fact, or, at least, sufficiently familiar with it to avail themselves of the very excellent data that is thus being compiled by the central bureaus. In my own practise as an engineer I have found indispensable the water supply and power reports and the topographic sheets of the Geological Surveys, the charts of the Coast and Geodetic Surveys, and the numerous reports on irrigation and drainage put out by the office of Experiment Stations and the Bureau of Soils. Mr. Hoyt's paper is therefore timely and valuable in pointing out the extent and character of these Government publications and the method of obtaining them.

The chief criticism that may be offered in respect to this Government work is that it has not been sufficiently extensive. The future growth of the western States in particular, is dependent upon the development of their power and irrigation pos-

sibilities, and these possibilities cannot be properly estimated or adequately exploited without definite knowledge of their physical aspects in the form of maps indicating geography and topography, and of records as to the amount and character of stream discharge. Furthermore, stream data to be of highest value must extend over long periods and must be in readiness for the psychological moment when financial and industrial conditions most favor the launching of new enterprises. Every engineer, investor and promoter knows how meager are the available physical data for the exploitation of new enterprises, how seriously development may be retarded on that account, and how frequently the lack of sufficient preliminary data has caused utter failure of large enterprises, with its aftermath of delaying or stopping worthy prospective projects.

In the eastern States the public domain has already been largely exhausted, but in the west the Federal Government and the individual States are still in possession of extensive bodies of land, there being, for instance, in the State of Oregon alone, about twenty million acres of vacant public land. Despite the very commendable work that the Government is doing, it is a fact that these vast territories may still very largely be classed as *terra incognita* as far as any definite knowledge of their engineering possibilities is concerned.

What would we, as individual owners of a large body of land capable of profitable development, think of a superintendent who had failed to make a study of the possibilities of the area under his control? If, after a superintendency extending over many years, he were unable to point out to us the boundaries of our land, and the names and locations of the water courses which traverse it; if he knew nothing of the character of the soil, the distances between important points on the tract, the amount and character of stream flow; of the possibilities for power development or of the location of mineral deposits; what, I say, would we do with such a superintendent, assuming of course that the responsibility for this lack of information rested upon him?

The Government, whether State or Federal, stands exactly in the relation of a superintendent or trustee for the people, and it is incumbent upon these agencies to make continuous, reliable and adequate studies and inventories of all our resources in order that such data may be ready at hand for directing and encouraging rapid development along proper lines.

The various State and Federal Bureaus whose duty it is to perform this work have appreciated this responsibility and have thus far done most excellent work, but they have been eternally hampered by lack of funds. For some unexplainable reason, each session of our legislatures and of the National Congress witnesses an effort on the part of our lawmakers to cut down appropriations for the purposes named to the lowest possible limit, reserving their bounty too frequently, as we know, for "pork barrel" expenditures and projects wholly without merit. Millions upon millions of useless appropriations have thus far been made, while our National and State domain remains to a large extent unmapped, and our magnificent water resources to an even larger extent unstudied. Within recent years an effort has been made to stimulate this work by a system of co-operation between the Federal and State governments, the Government bureaus offering to appropriate equal sums with the States for the carrying on of their common work. This has in a measure resulted in securing larger appropriations for both agencies. These appropriations still fall far short of what the importance of the work done would justify.

The United States Geological Survey has been especially active in this co-operative endeavor and some statistics of its work may be of interest. I found that in 1910 the Government expended for investigating stream flow $100,000, while 52 States contributed $52,850; and for topographic work the figures were, respectively, $434,200 and $159,238.

I have prepared a statement of data on this subject which is as follows:

STREAM FLOW INVESTIGATIONS IN THE UNITED STATES for 1910 and 1911.

Fiscal Year	Gov't Funds Expended	State Co-operative Funds Expended	Gauging Stations Maintained
1910	$100,000	$52,850	878
1911	150,000	49,129	1,105
	Topographic Work		Area Surveyed
1910	434,200	159,238	32,808 sq. m.
1911	434,200	138,983	23,496 " "

TOPOGRAPHIC WORK IN THE UNITED STATES FOR 1910 and 1911.

Year	Total Area Surveyed to Date	Per cent of Whole U. S. Mapped
1910	1,107,765 sq. m.	36.5
1911	1,131,261 " "	37.3

Average yearly increase almost 1 per cent.

STATE CO-OPERATION, 1910

State	Water Resources	Topography	Total
Minnesota	17,500	10,000	27,500
California	9,000	14,000	23,000
Texas	.....	20,000	20,000
Louisiana	.....	20,000	20,000
Washington	5,000	10,000	15,000
West Virginia	.....	15,000	15,000
New York	5,000	7,000	12,000
Maine	3,300	3,500	6,800
Oregon	2,500	2,500	5,000
Kentucky	.....	5,000	5,000
Missouri	.....	4,500	4,500
Pennsylvania	.....	4,238	4,238
Maryland	.....	3,000	3,000
North Carolina	.....	2,500	2,500
Utah	2,000	.....	2,000
Michigan	.....	2,000	2,000
Virginia	.....	1,750	1,750
Iowa	.....	1,750	1,750
Massachusetts	1,050	.....	1,050
Vermont	1,000	.....	1,000
Idaho	2,000	.....	2,000
Illinois	2,000	17,500	19,500
New Mexico	2,500	.....	2,500
Ohio	.....	15,000	15,000
Total 24 states	52,850	159,238	212,088

STATE CO-OPERATION, 1911

State	Water Resources	Topography	Total
Alabama	.....	800	800
Ohio	.....	25,000	25,000
California	9,000	14,000	23,000
Colorado	545	.....	545
New York	11,089	10,000	21,089
Washington	5,000	12,500	17,500
Illinois	3,000	13,750	16,750
West Virginia	.....	12,000	12,000
Maine	1,000	9,500	10,500
Kentucky	.....	10,000	10,000
Minnesota	.....	8,000	8,000
Pennsylvania	.....	5,183	5,183
Oregon	2,500	2,500	5,000
Idaho	5,000	.....	5,000
Missouri	.....	4,000	4,000
New Mexico	3,170	.....	3,170
Tennessee	.....	4,250	4,250
Maryland	.....	2,000	2,000
Massachusetts	825	.....	825
Michigan	.....	2,000	2,000
Utah	2,000	.....	2,000
Iowa	.....	1,750	1,750
Virginia	.....	1,750	1,750
Vermont	1,000	.....	1,000
Hawaii	5,000	.....	5,000
Total	49,129	138,983	188,112

Of the co-operating States Minnesota led the list in 1910 with $27,500 for stream flow investigation and topography, and Ohio, in 1911, was first with $25,000.

Our own State of Washington appropriated $15,000 in 1910, and $17,500 in 1911, while Oregon, which knows as little of its resources as any State in the Union, provided the sum of $5,000 only. The chief thought that has been suggested to me by Mr. Hoyt's paper is the urgent need of rapidly extending the investigations by State and Federal agencies. I believe that no more efficient method for self-exploitation and self-development could be adopted by any State than that of making wholesome appropriations for the scientific investigation of its physical resources. Such investigation and knowledge must precede any rational developments, and that State will develop most rapidly which in largest measure knows itself. Instead of utterly inadequate annual appropriations of from $2,000 to $25,000 now being made by the States there should be appropriations of from $50,000 to $200,000 per year, and the meager Federal appropriations should also be greatly increased. This can only be brought about by impressing its needs on the minds of our State legislators and our Congressmen through the media of our individual preachment and influence, and the influence of such organizations as the one you here represent.

Mr. J. A. Britton, San Francisco: I would like to ask Mr. Parker for information as to what extent the hydro-electric companies are co-operating with the Government in the gathering of data, particularly of stream flow, and whether any effort has been made by the Government to co-operate with these companies? I ask this question because on the Pacific Coast, particularly in central California, it may be said that the Government has probably perfected its topographic map to a greater extent than it has in any other State. It has presented us perfect maps that are in daily use in our territory and I know our company at least has, in a minor degree, co-operated with the Government, is in touch with Government officials and is constantly furnishing them data on rainfall, run-off of streams and such things.

(Chairman Doherty here requested Mr. Tait to take the Chair.)

Mr. Doherty: I was in hope that the paper by Mr. Hoyt would be particularly studied from the viewpoint of how the

Government work could be made of more interest and of more value to us. As we all know, there are a great many streams where the records of gauge readings run back for a few years only while the rainfall record will as a rule run back for a great many years. It is not unusual to find a stream charted with only 2 or 3 years' records of gauge readings, and 30 to 35 years' of rainfall. Now the puzzling problem always in cases where no gauge readings are recorded is the relation of run-off to rainfall. Each water unit has its own characteristic as to primary cause for run-off; that is, how much lag there will be from the rainfall to the run-off, and what percentage of the rainfall will represent the time in actual run-off. Generally speaking, a very light rainfall would not run off because it would all evaporate. Now the run-off curve follows the rainfall curve more or less, depending upon the amount of rainfall. That is, with a very light rainfall there is none on the dry ground, whereas when you have an exceedingly heavy rainfall you get almost 100 per cent run-off. The Government on a great many streams has not only gauge readings but rainfall readings, and if the Bureaus could add to their work something to show the relationship of these to run-off they would give an indication to the engineer as to how to figure on the streams and other watersheds.

Mr. W. N. Ryerson, Duluth, Minn.: In answer to the question Mr. Britton asked, I will say that in Minnesota the work of gauging streams was shared by the State and the Government, and in that State we hydro-electric companies were asked to assist, and did so very largely. I might add, in answer to Mr. Doherty's question, that in their reports the Bureaus give very good figures, so far as we have any way of checking them, as to the relation between the rainfall and run-off of the various streams.

The Chairman: If there are no further questions, I will call upon Mr. Parker to answer the questions that have been asked, and to close the discussion.

Mr. Parker: Mr. Britton has asked about the co-operation of the Government with hydro-electric companies. In the last four or five years such co-operation has been largely carried on in all sections of the country, and in Washington and Oregon, where I am especially familiar, I believe that practically all the

large companies are co-operating with the Geological Survey. The usual method of procedure is for the company to furnish daily observations of the stage of the river and for the Government engineers to make the measurements of discharge, which, with the gauge heights, enable the computation of the daily flow of the stream. In many cases where there are no measurements of gauge height or discharge, estimates of flow are obtained from data in regard to the electrical output of the plant and the records of the turbines.

Mr. Doherty has brought up the question of the relation between the run-off and the rainfall. There has been much debate among engineers in regard to this relation and it is believed by the Geological Survey that the use of estimates of flow upon this basis is liable to lead to serious errors, owing to the many conditions which enter in to affect the run-off. In general, the discharge of a stream is governed by five factors, namely, climate, topography, geology, vegetation and works of man. The effects of these factors are largely inter-related, and it is difficult to distinguish them in any particular case. The rainfall, which is a subhead under climatic conditions, is the principal factor which governs the total amount of run-off. Its distribution, however, throughout the year is very largely affected by the other factors. Within the last year the Geological Survey has made a study of all available run-off and rainfall data in the United States, and from the results two maps have been compiled, showing, respectively, the lines of equal run-off and rainfall, so that one can judge, in a general way, the relation between the two and also get a general idea as to the amount of run-off that may be expected in various sections of the country. These maps are only intended to show conditions in a general way.

The Chairman: I am sure I voice the sentiments of all when I say that we are very much indebted to both Mr. Hoyt and Mr. Parker, and I have no doubt we shall have occasion to refer to this paper many times in the future.

We will now proceed with the second number on the program, the report of the Power Transmission Committee, Mr. J. R. McKee, Chairman. I will ask Mr. Rushmore, of Schenectady, to present this report.

REPORT OF THE POWER TRANSMISSION COMMITTEE

The Power Transmission Committee, of which I have the honor to be Chairman by your appointment, has been unable to hold many meetings because of the personnel of its membership.

The Committee, you will recall, includes Mr. John A. Britton, of San Francisco, an official of the Pacific Gas and Electric Company; Mr. H. M. Byllesby, of Chicago; Mr. Henry L. Doherty, of New York; Mr. W. W. Freeman, of the Brooklyn Edison Company; Mr. F. P. Griffith, of Portland, Oregon, identified with the Portland Electric Light and Power Company; Mr. D. L. Huntington, of Spokane, Washington, identified with the large electric lighting and transmission interests in that city; Mr. Samuel Insull, of Chicago; Mr. S. Z. Mitchell, of New York; Mr. H. H. Porter, of Sanderson & Porter, New York; Mr. Charles A. Stone, of Stone & Webster, Boston, and Mr. O. B. Willcox, formerly of Denver and later of New York City, of William P. Bonbright & Company.

As far as water-power developments are concerned this list represents largely the sources which have been identified with the providing of a large proportion of the funds that have gone into developments of this character, scattered broadly the country over.

The Act of the Federal Administration withdrawing all public lands on which there was a possibility of a water-power site—doing this pending what is termed classification and a decision as to how and under what conditions they might be restored to entry—was submitted to your Committee for general discussion and suggestions as to the conditions under which capital might be induced to aid in their development if the Government restored these lands. The opinion, after thorough discussion, was practically unanimous that all franchises granted by the Government for water-power development on Public Lands ought to be "indeterminate" as to time limit, it being recognized that the Government would at the same time reserve the right to regulate charges, either by direct Federal control or through Commissions in the respective States where the property

is located. A Special Committee appointed for consideration of this subject by the American Society of Electrical Engineers also adopted a resolution expressing this opinion.

As Chairman of your Committee I, as well as Mr. Dunn, President of the American Society of Electrical Engineers, appeared before the Burton Congressional Committee, at Washington, November 21 to 24, 1911, at a hearing held on this subject, and made recommendations accordingly.

Politics under the name "Conservation" enter so extensively into the situation that those in Congress who have been trying to get legislation which might afford some solution find it very difficult to make progress. The result is that millions of acres of Federal lands are still withdrawn from entry and the undertaking of any new developments has in many sections of the country been discontinued. It is an ill wind that does not favor some locality, and the stopping of the development of water powers in the western States has served only to divert capital to the southern States where "Conservation" is interpreted as best accomplished by making developments. The result is that millions of dollars are being expended on water-power properties in the south, while those in the west are waiting for Congress and Federal officials to decide upon terms for the re-opening of the Government lands on some basis which will be attractive to capital. The attitude of the Federal Government on this subject has changed very little during the last few years. The Honorable Walter L. Fisher, Secretary of the Interior, says, on page 12 of his report for 1911:

"The present laws relating to water powers are hopelessly inadequate. The protection of the public interest is supposed to be accomplished by the statutory provision that permits for the development of water power shall be revocable at any time at the will of the administrative officials. This is thoroughly unsound both in principle and in practise. Many of those who would be willing to invest capital in the legitimate development of water power, but who wish to have the security which legitimate development rightfully demands, are unwilling to risk their investment on a tenure revocable at discretion."

In the President's Message of December, 1910, the following paragraph occurs:

"I am bound to say that the time has come for a halt in general rhapsodies over conservation, making the word mean every known good in the world, for after public attention has been aroused, such appeals

are of doubtful utility and do not direct the public to the specific course that the people should take, or have their legislators take, in order to promote the cause of conservation. The rousing of emotions on a subject like this, which has only dim outlines in the minds of the people affected, ceases after a time to be useful, and the whole movement will, if promoted on these lines, die for want of practical direction and of demonstration to the people that practical reforms are intended.

"I beg of you, therefore, in your deliberations and in your informal discussions when men come forward to suggest evils which the promotion of conservation is to remedy, that you invite them to point out the specific evils and the specific remedies; that you invite them to come down to details in order that their discussions may flow into channels that shall be useful rather than into periods that shall be eloquent and entertaining without shedding real light on the subject. The people should be shown exactly what is needed in order that they may make their representatives in Congress and the State Legislatures do their intelligent bidding."

The last paragraph to the effect that the people should use their influence on their representatives in Congress and in the State Legislatures is the essence of the situation, and it is for those who read this paragraph and are interested in the subject to decide how they can assist their representatives in the endeavor to bring about a sane and practical solution of this problem. It is also for those who have had experience in investigating and developing water powers to give to those who have charge of legislation the benefit of their observations and recommendations as to what should be undertaken to restore for development properties scattered throughout the country, where to-day millions of horse-power which might be utilized are running wastefully to the sea.

Situations which are typical are found in nearly all sections of the country. For example, the study of Niagara Falls by United States Government engineers has produced interesting data. I think very few who have seen Niagara Falls realize that of the total amount of water coming down the river only five per cent (5%) goes over that part of the Falls located between Goat Island and the American shore; in other words, the American Falls.

An interesting fact brought out by the Engineers' investigations is the retreat of the mean trend of the apex of the Horseshoe, or Canadian Falls, of one hundred and seventy (170) feet between 1875 and 1906. This means that the Falls on the Canadian

side are retreating at a rate in excess of five and one-half feet per year. At the same time, the Falls on the American side have remained as they were at the time of the observations made in 1875. This is due, of course, to the fact that a much larger quantity of water, in other words, 95 per cent of the total, passes over the Canadian Falls. A study of the topography of the Falls and of the present trend would seem to indicate that in the course of years all the water will be pouring over the Falls towards the Canadian side. If some way could be found to reduce the amount going over the Falls, passing it through some other channel, would it not be contributing towards preserving the life of the Falls? Let us investigate what the withdrawing of an additional amount of water would mean as affecting the scenic grandeur of the water pouring over the crest.

On page 15 of Senate Document No. 105, Sixty-second Congress, occurs the following paragraph:

> "For every additional thousand feet diverted in the Chippewa-Grass Island pool, the crest of the American Fall will be lowered 0.002 feet; that of the Canadian Fall at Terrapin Point 0.004 feet; and at its west end 0.027 feet." (Should be 0.0027 ft., *J. R. M.*)

It is only fair to say that other data in the report are not entirely consistent with the figures given in this paragraph and would seem to indicate a somewhat larger fluctuation in the water than is shown by these figures; but, whatever the variation, it is measurable in inches and fractions.

The Convention entered into between the United States and Canada restricts the quantity of water to be taken from Niagara River to 20,000 cubic-second feet on the American side and to 36,000 cubic-second feet on the Canadian side. On the basis of the figures given above, the result of withdrawing this total quantity of water (56,000 cubic-second feet), would be to lower the water at the crest of the American Falls one and three-eighths (1⅜) inches, and at two points on the crest of the Canadian Falls one and seven-eighths (1⅞) inches and two and five-eighths (2⅝) inches, respectively; measurements which are hardly discernible by the eye. Personally, I think these figures, although based on the data quoted from the Government Engineers' Report, are only approximately correct, and that the diversion would, in depth of water, be probably double and

more the number of inches stated. Neither amount, however, could be charged with having any influence on the scenic grandeur of the Falls. It would appear, on the basis of the Government report, that a still greater quantity of water could be withdrawn from above the Falls, and that doing so would in fact be beneficial, as tending to preserve the life of the Falls, particularly on the Canadian side, by reducing the washing away or recession of the crest, at the same time not affecting perceptibly the flow over the American side, if utilized in the most advantageous way by withdrawing it from the river as far above the Falls as, say, La Salle, which is a number of miles above the Falls. If, for instance, you were to divert an additional 20,000 cubic-second feet and canal it across the country well back from the Falls, so that it could not possibly interfere in any way with the beauty of the Park as a whole and turn it back into the river again at or below Devil's Hole, this amount would develop a continuous 500,000 horse-power, and would decrease the quantity of water going over the Falls by an amount hardly appreciable to the eye. This 500,000 continuous twenty-four hour power at the very low rate of $20.00 per horse-power year would mean ten million dollars annually added to the world's wealth. I fix on this amount of water because there is such a grant outstanding by Act of the Legislature of the State of New York, not used by reason of the arbitrary ignoring of this grant by the officials of the Federal Government although it was brought to their attention when the Convention was entered into between the two countries.

We are so accustomed to idly watching water that flows past that we lose a proper comprehension of what is actually being wasted in energy. If I should, however, by some legerdemain be able to take you to a certain point and show you a body of coal sufficient to produce 500,000 continuous horse-power which was sliding off the side of a mountain into some dark and cavernous depth where it would be irreclaimably lost, you would stand appalled at the extravagance and waste, especially if I were to tell you that it could be easily saved if the Government officials would allow it, but that because of their arbitrary attitude the awful waste must go on unchecked. Similar situations exist in greater or less degree all over the United States and are exploited by Federal officials as "Conservation." Picture

to yourself what this 500,000 continuous horse-power would mean if applied to the products of the country. For instance, 60 per cent of all the power now generated at Niagara on the American side is used in electro-chemistry. With this power many articles are produced commercially and become available for the use of mankind. Localities are built up. The wealth of the world is increased. Economy in living is attained in proportion to economy in the cost of production. The obverse of this is, this wealth untold is running to waste year in and year out, when it could and would be utilized for the benefit of mankind but for Governmental interference.

Apply this line of reasoning to some development in your own locality and lay your conclusions before your respective representatives. Let us see if we cannot replace rhapsodies with some common-sense views and get some sensible legislation enacted so that these millions of acres of public domain now held up and unavailable for development can be put to use.

So far as legislation is concerned, two bills have recently been introduced by Senator Burton known as Senate Bills No. 6795 and No. 6796. I do not believe that these bills could be satisfactory to those who would be expected to furnish capital for the development of water powers in the public domain. I would suggest that you secure copies of these, if you are interested in this subject, as I think you are, study them carefully, and give your Congressmen the benefit of your recommendations for their amendment in connection with any hearings which may be held. I believe it is generally held that so far as the public domain is concerned there are no legal conditions under which the Federal Government can grant rights for the development of water powers located therein. This, of course, means that no new filings are being undertaken for water powers within the public domain. As for granting rights on navigable streams, each case requires a separate Bill through Congress, and the terms which are attached to such grants are so onerous that it is surprising any should have been accepted, although some have been, where conditions were urgent.

Ignoring legal conditions for the moment and touching upon electrical developments in the transmission of power, a most interesting step made since your last Convention is in the plant of the Au Sable Electric Company, in Michigan, where a line

using steel towers, with ten suspension-type insulators in series to support each wire, three petticoats on each insulator, and with No. 8 copper wire (7-strands) strung from 12 to 17 feet apart, has transmitted power successfully for several months at 140,000 volts over a distance of 120 miles. Another important transmission plant now under consideration is that from Big Creek, in California, with contemplated transmission to Los Angeles, a distance of approximately 275 miles. Aluminum wire is to be used, and they are giving careful study at present to the feasibility of sending as high as 180,000 volts.

Reverting to the discussion of water powers it might be well first to consider the question of water supply and invite notice to the contentions which are being brought forward by some writers on this subject. Specious arguments are constantly advanced, and they are not without plausibility, to the effect that all waters should be treated as a unit and come under the control of the Government.

It is sufficient to say in closing that the general conditions regarding water powers which are located in the public domain are wholly unsatisfactory and there is no present legal provision under which they can be made sufficiently attractive to invite funds for their development.

It is hoped that in time further study of the situation on the part of the Government officials and conferences with those who would be active in such development may result in some mutually satisfactory solution of the problem.

Respectfully submitted,

Committee

J. R. McKee, *Chairman*
John A. Britton
H. M. Byllesby
H. L. Doherty
W. W. Freeman
F. T. Griffith
D. L. Huntington
S. Insull
S. Z. Mitchell
H. Porter
C. A. Stone
C. B. Willcox

THE CHAIRMAN: I wish to announce that it has been requested that Mr. Doherty supplement the report of this Committee by repeating that portion of his address which refers to the attitude of the Government towards the development of the water-power.

MR. DOHERTY: The portion referred to, gentlemen, covers only about three pages. It is my individual view of the situation, and does not bind the Association in any way. Before I read this I want to answer several criticisms that were made by those who heard it last night, and also to repeat what I said to one of my friends who regretted that I expressed myself in what he termed an intemperate manner. My defense is this: It seems impossible to discuss this problem of conservation, or this idea of conservation as it is now exploited, and arrive at anything when keeping the tone and the manner of an academic discussion of an engineering problem. For instance, I do not hesitate to say that I think the men who are exploiting the present policy are not looking for the real truth, but rather are looking for a public issue, and while I have gone beyond proper form, it seems, in the strength of my statements, I believe I am fully justified in doing so. I will take just a moment of your time to tell you of a situation that perhaps you all realize exists and is harmful to us, without knowing the source of the trouble. Five years ago I was in Germany. I had been asked by a prominent banking house in this country to take up with a London banking house the matter of selling a large issue of preferred stock. The London house refers me to a German house, and I went to see the head man. He told me that nothing could be done, that they could not buy this stock. He was very courteous, while refusing to do business with me, and volunteered to drive me around to the electric light plant which I wanted to see before leaving the town. When I got off he waited to see whether I could get in with no other introduction than a calling card. The chief engineer knew of me through my perpetration of the rate paper, and I got into the plant, this young man going out to the banker to explain that I was all right. That man's attitude immediately changed and he asked me to come into the bank that afternoon at four o'clock. When I

went in after four o'clock he said, "I don't know but what we can do something with that stock issue. It makes a difference if you are personally known in this city." I said, "I am not personally known. This man knew of me as my name is identified with the electric lighting business." "Well," he said, "I think that makes some difference, and I believe we can do something with that issue of stock. You see, we are afraid of Americans over here. We do not like to take up any issue of stock or any of their financial schemes unless we know thoroughly well who they are." I was careful to inquire from this man where he got his opinion of the American business man, and he referred me to our own public officials and our own magazines; they were his authority for believing that the American business man is dishonest and has to be watched.

Now, travel Europe over and you will find that belief is prevalent except in those houses that are thoroughly familiar with American business methods, and are dealing with Americans every day. If you go to London into their large banking houses and try to associate yourself with any of these, they will probably give you a courteous hearing and bid you good day; and they will then go off and finance some scheme in Mexico, South America or South Africa, simply because they have been told by our home publications and by our own public officials that the American business man is too dishonest to be trusted. So, if I see fit to reply to these men and do it in a way which is so emphatic as to seem intemperate, you have my reason for the language I use.

The part of my address that it has been requested I should read in connection with Mr. McKee's paper, is as follows:

"It is rather interesting to note that the greatest obstacle to the development of the millions of horse-power of hydraulic energy still unused is the United States Government. Under the guise of the Conservation of our natural resources a remarkable school of political economy and statesmanship has sprung up. It would be humorous were it not so serious. We are told that we must conserve our natural resources for the sake of posterity, and we have been saddled with an alleged plan of conservation which has brought about the most flagrant and inexcusable waste, which has stagnated development and prosperity of our great western country and has turned the stream of pioneer settlers toward Canada.

"For many years the conservative statesmen of this country have regarded the public lands as a public trust to be used for the development of the section in which they are situated, but the new school of alleged statesmen, after inaugurating a campaign of misrepresentation and hysteria, have construed the ownership of the public lands to be theoretically for the enrichment of the Federal treasury, although in practise millions of dollars have been spent or wasted in applying the mistaken theories of impractical men.

"Areas more than one hundred times greater than some of our smaller eastern States have been withdrawn from entry since this conservation policy has been ushered in. Millions of tons of coal have been mined and burned to furnish power that might have been generated by water that now runs idly to the sea.

"Millions of acres have been withdrawn from entry and much reserved for National forests primarily on the theory that this policy conserves the flow of the streams. It is certainly not proved that the forests do conserve the flow of the streams and it is a matter capable of easy proof that forests do not conserve the flow of the streams as well as the tilled soil does.

"The public lands instead of being assets to the States in which they are situated have become a great obstacle to their growth and development. Great railroads cannot be operated successfully when large stretches of unproductive, uninhabited lands must be passed. Natural development is thus discouraged and retarded. Large numbers of our desirable western farmers are migrating to Canada. Water-powers that might be constructed and which would bring about new industries are lying idle and it is not to be wondered at that many intelligent people express contempt for conservation when in reality they intend only to fight this false form of conservation that has been thrust upon them by an impractical school of fanatics and theorists.

"The opposition of the Government has spread to other Bureaus and it is now almost equally difficult to get permission to make a water-power development on the navigable streams, even although many of these so-called navigable streams are navigable only by chips and small logs. Permission is now being sought for a reservoir on one of these navigable streams which is in fact non-navigable, and in addition to the other burdens which the Government wants to propose, the Secretary

of War insists that the builders shall pay such rental for the site as the Secretary of War may fix from time to time, and in addition to this the Secretary of War shall have the right from time to time to regulate the rates charged to consumers. This particular reservoir will be a small portion of a large steam generating and distributing system serving over 200 square miles of territory in two different States. Imagine the Secretary of War adding to his legitimate duties the regulation of electric rates, and the poor electric company submitting not only to the inherent regulation of rates that each State undertakes for its public service corporations, but to those of the Secretary of War as well.

"We are passing through a period when the builders of the great enterprises of the country are regarded as public enemies. Building operations have been carried on for the past five years at less than normal rate and a period must soon come when the continuation of this condition will bring the whole country to a low ebb of prosperity.

"I cannot but contrast the policy of the administration of this country to that of Germany. History will paint the German Emperor not as what we see him caricatured to-day but as the man who retrieved German commerce and industry. The enormous German immigration which helped for many years to populate this country has almost ceased, and only recently I was told by the publisher of a large German newspaper that the day was fast approaching when there would be no call for a paper such as his, published in the German language. In Germany if a man builds up a great enterprise they decorate him, but in this country we try to send him to jail. The German policy has told its story in the wonderful prosperity which an apparently disintegrating country has attained in a few years, and our policy, if continued, will in time tell the opposite story.

"The policy of our Government is simply another symptom of a widespread hysteria. The people believe there is something wrong and stand ready to follow any unscrupulous demagogue or impractical dreamer who promises to correct these wrongs, and, as in our conservation movement, practically everything that is done accentuates the wrongs of which they complain rather than corrects them.

"In spite of the statements of our new school of alleged statesmen and our muck-raking publications, the American business man is the most honest and reliable of his class in any country and this statement is borne out almost universally by the foreign business men who do an international business. His reputation is maintained in spite of the army of muck-rakers who never fail to accord a gratuitous insult to the American business man whenever opportunity affords, to the great delight of our many foreign enemies.

"I wish that we could quit fighting symptoms and devote our time to the underlying disease. The public has come to believe there is something radically wrong in our business methods and seems to be willing to follow any man, no matter how incompetent he may be, provided he is sufficiently intemperate in his speech.

"If wrongs exist they should be corrected, and if these wrongs are imaginary they should be explained away. The business men of the country should inaugurate a new move, if not for their own protection, then to free the great mass of our people from incompetent leadership which can only bring harm to all of us as a nation."

(Mr. Doherty here resumed the Chair.)

THE CHAIRMAN: Our next speaker is probably better qualified than any other man in the country to advise with us as to how we can unlock this large store of latent wealth in the form of water-powers that has been withdrawn from entry. We have invited him to address us on this or any subject along these lines which he may choose. We believe in his energy, his knowledge and his ability to tell things exactly as they are.

I want to introduce the Hon. R. A. Ballinger, formerly Secretary of the Interior.

(Judge Ballinger was greeted with enthusiastic applause, which continued for three minutes.)

MR. BALLINGER: Mr. President and Gentlemen of the Convention: I most heartily appreciate your greeting. I am glad to be able to be here for a few moments.

I was at one time greatly interested in these subjects pertaining to the Public Domain, but for the purpose of making an honest living through my profession I have been endeavoring

during the last year to forget very much of my connection with public affairs, particularly the political relations connected with public affairs.

Speaking of conservation, Mr. Doherty calls to mind by his remarks a species of conservation that is being greatly symbolized in this country. This was worked out by one of the members of the Geological Survey, but I think you will not find it in the Geological Survey reports. It was stated by this prominent member of the Survey that there are something like a million tons of Epsom salts going to waste every year through the Colorado River into the Gulf of Mexico. He figured out just what portion each individual citizen of the United States was losing in Epsom salts, and how much capital was going to waste through Epsom salts. This is a fair illustration of some of the wild fancies of the conservationists.

Getting, however, to the subject of the public domain and the question of power development on the public domain: When I was Commissioner of the General Land Office in 1907, we knew of no classification of public lands that related to power sites. Such a division or classification of the public domain in the distribution of public lands had not been heard of at that time, either by Congress or the Federal officials. Shortly thereafter, however, it became one of the great programs of the conservation movement and, regardless of any legislation by Congress, it was determined that all of the possible power sites in the public domain should be reserved for posterity.

You gentlemen understand, as very citizen of this country understands, that the public domain was placed in the hands of Congress and not in the hands of our executive officers for disposition. The executive officers are merely the instruments of Congress in its disposition under such laws as Congress may enact. Congress has the power to give away the public domain if it sees fit, and the great development of the public lands in this country began in the Sixties. Perhaps the principal development came through the Homestead Act, which Abraham Lincoln signed, and the Mineral Act of the Sixties, laws which expressed, both in terms and by implication, that the public domain was open, in limited areas, to intending settlers or intending explorers, for the purpose of development, and was to be given, in limited areas, to the *bona fide* settler or the *bona fide* explorer,

for the development of the nation. No more beneficial policy, no more liberal or generous policy, was ever adopted by any government. We may say, and perhaps rightly, that the Government was very generous, was reckless, perhaps, in some instances, in its grants for the development of the public domain. But, nevertheless, is it not better that a State should be developed out of a wilderness and that people should be enabled to exist on the natural resources of a territory than that the wilderness remain a wilderness, and natural resources retain their forms undeveloped or be lost forever?

No one will contend that Colorado or the State of Washington, or any of these western States does not contribute more to the Union to-day, to the happiness of the American people to-day, because of the introduction of settlers, of the introduction of men who have explored the natural resources and have made it possible for our Congress by informed legislation to contribute to the domestic and civic happiness in those communities. The wealth of the nation has been increased as well as the happiness of the nation, and the theories of conservation as expounded by the extremists are ridiculously impractical, are utterly absurd under the American system by which we have from the beginning of this government undertaken to inspire individual enterprise, to inspire the development of our resources, and to encourage the genius of our people, individual and collective. Nothing has contributed more to this development, nothing has contributed more to bring out individual American character, than the freedom and openness of the public domain.

I may, perhaps, be the beneficiary of some of this individually, for in the Seventies I herded cattle on the plains in Kansas and assisted my father in developing and securing a soldier's homestead, a bounty from the Federal Government.

The people who have been developed through these encouragements are the bone and sinew of the American nation to-day, and in my judgment they are not people who are going off to extremes in social remedies or to extremes in political expediencies; they are not the people who desire to change our institutions or the fundamental law of our Government, who are attacking the Constitution and attacking the laws. They are people who stand by the flag and stand by those things which to the minds of those who have gone through these experi

ences are sacred, are a part of the domestic and a part of the patriotic life of every citizen. [Applause.]

Now when we get to this proposition that the Federal Government undertake to control the water-power resources of the public domain, what do we find?

We find that through laws that have been upon the statute books for a great many years, well, say from 1866, the first rights-of-way were granted with a view to opening canals and ditches for mining operations. We find that under these Acts the public lands have been distributed by patents for homesteads, patents for desert land entries, timber culture acts, mineral patents and others, until the power sites that have passed into private ownership are greater in number than those which still exist in public ownership, so that in all of these western States where the public domain exists, the greater portion of the power possibilities, hydro-electric power possibilities, are already under private ownership.

The Federal Government has attempted to reserve the power of permanent control, although it has not cast it into legislation further than the Federal Rights-of-Way Acts, which still exist, yet all of those Acts were intended to give a free easement to development. I say the policy it is now attempted to inaugurate is that the Government shall undertake the supervision, control and disposition of the power sites upon the public domain. Now let us stop a moment and see what the attitude of the Federal Government is in this. Every State that came into this Union came in under the same conditions and with the same rights and privileges as the older States and as every other State. The State of Washington, in which we now are, has the right under the Constitution to have extended to it and to enjoy the same privileges and benefits as every other State in the Union. The eastern States and the middle west States have had the benefit of the exploitation of the public domain within their borders and the disposition of all the power sites that remain within them, as the public lands are now practically all gone within the middle West and in the Rocky Mountain and Coast regions. There are some yet in Alaska, however, and I presume they will remain public lands from all appearances as to the attitude of Congress. [Laughter and applause.] The Federal Government is undertaking to set itself up in the power-site business

or the power-disposition business—I do not know exactly what you would term it—alongside of people who have acquired these private rights, and directly in competition with them.

It was never contemplated, in my judgment, that the Federal Government would stay in the public-land business or would become a landlord, so to speak, as far as the public domain was concerned. Reservations, such as the National Parks, and reservations for military and naval stations, for custom houses and other public structures, were necessary for the maintenance of the Government, and in so far as they were necessary and are still necessary, it is the duty of Congress to set aside such lands as are on the public domain for its own uses. But, as was said by Mr. Doherty, the remainder of the public domain is substantially a trust fund for the benefit of the newer States in which they are situated. [Applause.] Now, it is my belief that the Government ought to go out of this business of the public lands as soon as possible; that it ought to delegate it to the communities, to the people of the States in which the lands are situated.

We hear much discussion about the people, the rule of the people, and the control of their own affairs by the people. I agree with that, and I believe the people should control the public domain in the interest of the State where the public domain is situated. I believe that the State of Washington is entirely competent to take care of and discharge any obligation or trust that may be imposed upon it in the disposition of the remnant of the public domain within its borders.

A bill was introduced in Congress, I think it was by Senator Carter, in 1910, for the disposition of these water-power sites to the States, trusteed in a form that would compel their being disposed of for development only, and under reasonable restrictions imposed in the bill. This bill, of course, met violent antagonism from the ultra-conservationists. Why? If they were genuinely in favor of conservation and development, of making the best use of natural resources—for that is all reasonable and honest conservation means, making the best use of our natural resources, prudently and frugally—if they were honestly in accord with reasonable conservation, they would be in favor of permitting these power sites in the various States to be developed, trusteed to the State if it may be, but of keeping the Federal

Government out of it. They were, however, opposed to it, first of all because it interfered with bureaucracy, because it was a blow at the control of the public domain by these Federal officers. They did not purpose to lose their grasp upon the administration of the public land; nor do they intend to do so to-day. They are gradually drawing the strings tighter and tighter around the public domain and its disposition, as far as the western people, the people who ought to be enjoying the benefits of the public domain, are concerned. How are they doing it? By attacking every reasonable measure that is introduced in Congress, every measure proposing a program of development, even though the land remain in the hands of the National Government. Every bill unless it be introduced by the chief mogul of the conservation movement or one of his satellites is attacked by the organization, and the men who have the temerity to introduce anything in opposition to their theories are assaulted as being connected with the interests, possibly with the power-trust interests, whatever these may be. I have heard a great deal about it. I have been charged with being connected with it, but have been utterly unable to find anything tangible in connection with it, or to find where my interests touch it in any particular except in the bills I have to pay to the Seattle Electric Company and the other companies of that great concern. [Laughter and applause.]

Now it was proposed that the mineral laws be changed so that instead of a fee simple title passing to the mineral prospector or the man who has discovered minerals in paying quantities, he shall have only a license to mine. That is on the level of the doctrine of permits to use water-power in the National forests, advocated for a time shortly after the National forests were organized. The idea of leasing coal mines is another of the same species of doctrine by means of which the supervision by Federal power continues. The control by the Government officer is to be constantly there, and his finger to be upon the administration of the property.

I opposed, even under President Taft and against his ideas, the plan of leasing coal lands from the public domain. I contended that the man who leased coal mines from the Federal Government would have in their operation and development and in the mining of the coal a greater incentive to rob the mine than

if he owned it, and that you could get a better development by a corporation or an individual with private capital invested. Supervise if you will, but give such a title, give such an interest as will assure and enforce development, an economical development preventing unnecessary waste.

Waste! Waste! Waste! Prevent waste! That is the cry all the time, yet every suggestion that is made by the ultra-conservationists with respect to the handling of the public domain has in it the elements of waste, permits, induces, requires waste.

Take this matter of the idle, unused water-power of the west. By withholding the power sites by public withdrawal, there are going to waste every day in the year millions of horse-power. Mr. Leighton, chief hydrographer of the Geological Survey, makes the statement that if even a reasonable development were made to-day of the water-power going to waste, we could save more than one-third of the coal that is being consumed in the United States. I get pretty warm when I fall to discussing these matters, and I do not want to be intemperate in speech, because there is no way to reach these questions through intemperance of mind or of attitude. The only way to correct mischievous boomers in public affairs is by approaching them directly, temperately and wisely. Now, I presume any suggestion I might make publicly would be said, at least by *Collier's Weekly,* to be in the interests of the Interests [Laughter], but I said in Denver at a public meeting that I believed the Government ought to go out of the public-land business; that the States, as far as the power sites are concerned, should be given the right to administer them; that they should be trusteed to the States by grant or by a trust donation in such a way as would compel the States to perform their duties; if not done, those rights could be forfeited to the Federal Government, which has many ways of protecting itself in these matters.

Take the matter of the disposition of the other State lands, of the forestry, of the agricultural or the coal lands in a State, the title to which still remains in the Federal Government. It would be vastly to the interest of a State and accelerate development and increase of population enormously if these resources could be exploited and lands disposed of to intending settlers and people who have the natural right to invest in them without burdensome and ridiculous restrictions. Take the forest reserves

that run through this State from north to south, occupying perhaps more than one-quarter of the entire area of the State, in Idaho occupying, I think, something like one-third of the State. If this forest reserve was all consolidated into one corner of the State of Washington and along the border line on the other side, it would be vastly to the interest of at least the State of Washington if it could be cut off and thrown back on the Federal Government as wild territory. There it lies across the State, interrupting the development of power and water possibilities, the construction of railroads, canals, ditches, highways—everything. You have to go and consult a forest supervisor before you can even cut a twig or blaze a path.

This condition, gentlemen, I submit to you, under our American system of Government is intolerable, and no people except those born under the Anglo-Saxon system of government who respect law and order and the administration of law, would submit for any time to such domination of forest inspectors, supervisors and field-officers as we are subjected to to-day. A man who undertakes to make a settlement, even upon the public domain to-day, is harassed with inspection, harassed with the affidavits of men who are contesting his right, and if he undertakes to find a mineral location in a forest reserve or to make an agricultural settlement in a forest reserve, or to secure a water-power, does he find any open hands to receive him and assist him in the development of these lands? No. You know and we all know it is not the case. The intentions of the Government agent may be good, but settlers undertaking, as American citizens, to do their duty and secure rights under the laws of Congress are harassed until we find them crossing the border into Canada or into Mexico, or going to some further country.

The policy, in other words, is not only keeping capital out of this country, stifling development, but is driving our people, people whose energy we need here to develop this country and to work out our great problems, into other lands to secure more favorable opportunities for exploitation under other governments.

Now take Alaska. See what a protest she sent up the other day through that volcano. If I were consulted as an oracle I would say it was without doubt a protest against the way the United States Government treats that enormous territory to the north. [Laughter.] Of course we here feel more sensitive

about the condition of Alaska than do other sections of the Coast or of the country. Alaska is one of the greatest assets of this nation, the greatest storehouse of wealth, of water flowing upon the southern slope of the mountains, of deposits of minerals, and even of grazing opportunities for stock raising and of agriculture—its possibilities of wealth are largely unknown. It is a prize package; and yet our own Government will not let us open it, will not let us enjoy it, and here we are in Seattle, at the threshold practically of this great country, and Uncle Sam will not let us make anything of the opportunity.

I have, of course, been accused of trying to steal all the coal up there; but the Federal Government has not lost any of it. She still has it all; not a patent was ever issued for any of the coal lands in Alaska; not a pound of coal ever went under a patent from the Federal Government; and if the records should be examined it would be found that I had as much to do as any man with restraining the stealing of coal in Alaska. But that is neither here nor there. The coal lands of Alaska should be developed, and it is inconceivable to me that 1100 entrymen were all in conspiracy and fraudulently undertaking to secure some of these lands under the Federal Acts. I will not say there were 1100 individual entrymen, but 1100 entries appeared upon the records and were all classed by the Department of the Interior as fraudulent. In order to correct some of these difficulties in connection with the disposition of public lands, I undertook, with the assistance of the President, to secure the right of an appeal from the Secretary of the Interior to the courts of the District of Columbia, so that if any question or dispute arose between men seeking to secure rights from the Federal Government under the laws of Federal Government, the man denied his rights or seeking to protect his property would have an opportunity to get away from the arbitrary and discretionary decision of an executive officer who is not bound by the rules of courts of justice, and whose decisions or dicta became final and absolute. I know many instances, because of the lack of some such remedy, where the rights of the owner have been confiscated and his land taken away from him, with no redress whatsoever. Even though the settler may have been acting with the utmost good faith and have spent a large part of his active life in securing these rights, he has no appeal from

the arbitrary declaration of an executive officer. This is not in harmony with our laws; it is not within the spirit of our American institutions; it is not fair play; not a just determination of the rights of individuals, particularly individuals as against the Federal Government.

Now in closing, gentlemen, what should be done with the public domain? The western States have, I think, been recreant of their duty in not presenting their case to Congress and showing the necessity for such development as could be made and the impossibility of making development under the existing state of affairs. Of course, while I was Secretary of the Interior, under the existing regulations and the laws as they stood, I withdrew a million and a half acres of water-power sites, but it was under the Act which provided that this should be withdrawn until Congress furnished a method of disposing of those lands. Congress has not acted, and there it stands. I presume another half million acres have been added, probably a million and a half; I do not know what the withdrawals amount to now; they probably cover practically all of the water-power sites of the public domain.

But the western States have to make their case apparent to the eastern States. Thos people of the east do not intend to do us harm in the west. It is not the intention of the great mass of our brothers in the east to oppress their brothers in the west. They simply do not understand the west. They do not understand the public domain. They do not understand us, and they have been largely kept from understanding us by the lying, muck-raking, vile and vicious press and the magazine literature of this country. [Applause.] Correct the vice of your magazine literature, the vice of the press by which misrepresentation can be made of any man or any thing with impunity. I claim that truth is as much the right of an individual as life or liberty or property. The right to the truth is one of the inalienable rights of every citizen. [Applause.] We claim the right to reputation. Take away from a man the reputation he has struggled for and sacrificed himself for, and what is life to him? We claim the right to the truth about a man. He is entitled to it, and no man has the right to speak falsely of another, nor has any man or any set of men the right to speak untruths that unfairly affect an individual. The public is entitled to the truth fairly and

honestly stated about persons as well as about conditions. When our eastern brothers understand that nothing in nature is of any value lying hidden and concealed from mankind, they will help us in our struggle for the right to expand and develop. When we all understand better our right to truth, fair statement and fair play we will come out of the lethargy which now holds us and fight the hysteria and the vice that are hampering us, and the demagogue and the common liar against public news. [Great applause.]

I thank you for your expression of good-will and appreciation. I trust that the energy of these young men will spread itself to every part of this Union and make this blessed country what it ought to be, a thrifty, happy nation, for never in the history of the nation should it be enjoying more happiness than this very day. [Applause.]

The Chairman: The Power Transmission Section in its first activity called a public conference on the attitude of the Government towards the development of water-powers. I regretted exceedingly that we did not have Judge Ballinger and Mr. Britton there. We managed to make some progress, I think, and I believe that this meeting has done a world of good. The statements we have heard here to-day will at least make many men stop and think. I have no doubt there are men who came into this room believing that the policy of conservation as laid down by our fantastic friends was a wise thing for this Government. It is impossible for every citizen to study and understand every question that comes up. There are a great many people entirely honest in their intentions, who believe that this conservation movement which has locked up enormous areas of our country, is a wise policy and is benefitting the country. I do not believe anyone after careful study can recommend a continuation of that policy. If this section does nothing more than cause men to stop and think it will have accomplished good. The great trouble with the masses of our voters, with the masses of our people, is that they express opinions before they have studied questions as they should. Imagine the State of Washington with one-quarter of its territory stretched across the State incapable of producing anything to support railroads, barren land to all intents and purposes, that must be crossed to

get from one community to another, and imagine that condition in, for instance, the States of New York or Ohio or Pennsylvania. It would be bad enough there, but think what a tax it is here on the development of this new country. When we retard the development of this western country we retard our prosperity as a nation.

MR. ARTHUR WILLIAMS, New York City: Mr. Chairman, I move that the most appreciative thanks of this Association be tendered Judge Ballinger for his frank and stirring address to the Power Transmission Section on the question of power development in the Public Domain.

The motion was seconded and unanimously carried.

MR. RUSHMORE: Gentlemen, I ask permission to make a few remarks, not for Mr. McKee, because I am not at all fitted to explain his points of view, but for myself, not as a member of any company or organization, but based on a large amount of discussion and of very pleasant and interesting association with water-power developments, extending now over a good many years. I take it that we, and I say we as representing the bankers, investors, manufacturers and operators, we are all interested in the development of the industry, of the utilization and applications of electricity, and it is because we have such a common interest that a personal point of view is offered here.

We need to realize that a new generation is coming into action and that things are to be done on a somewhat different plan hereafter. There has been a very great change in the standard of business ethics in the last 20 years, and I think all of us realize that a great many things which were considered all right 20 years ago are now looked at from a somewhat different point of view. Many of the older generation in public life have been unable to see this and to adjust themselves to it.

If I remember correctly, the first public agitation on the water-power situation and the water-power, so-called, trust was an article in one of the popular magazines written by a man who unfortunately did not sign his name. He had been very unfortunate in the development of a certain enterprise, due to a gross underestimate or over expenditure in connection with it. A short time after, that same point of view was given forth publicly in a speech by the President, some of the facts, no doubt, having been passed up to him by his subordinates. Now

the facts in connection with any such condition are not available to everybody. The facts as set forth in the magazine article were as erroneous and strongly partizan as they could be made, but where was the other side of the matter to be read? How were the facts on the other side to be brought out?

I have had the opportunity of talking with a considerable number of Government officials in connection with water-power development and have been surprised at the lack of information they possess regarding both the engineering and commercial features of such enterprises. It is difficult to see how they could act upon or decide intelligently upon the questions and reports that must be submitted to them. The report just brought out by the Bureau of Operation on the water-power situation is an attempt to tally with the facts, I take it, but the conclusions drawn from it are the conclusions, naturally, of a man acquainted with but a very small part of the facts, or whose ability to interpret them is very much limited by an experience not inclusive of facts such as the members of this organization must naturally have.

I have certainly come to believe in the good intentions of the Government officials; in the good intention of everybody who is taking an active part in this campaign, in the good intentions even of writers of muck-raking magazine articles, but I believe as fully in their lack of correct information and their lack of power to reason correctly from a given body of facts.

Without going further into the question, there is no sharp line of demarcation between the activities of the Federal Government and the State Governments, and in this, as in other lines, in lines of the public policy organization and of all organizations of individuals, we are passing through a period of very rapid transition. This is shown by the agitation concerning municipal plants, by the almost nation-wide creation of public service commissions, by the existence of such schemes as that of the Ontario Hydro-Electric Commission, and the consideration of one much like it this present year by the State of New York. Many people are now questioning the justification for the present period of competition. With the advent of the public service commission controlling public utility corporations, the latter have been removed from the conflict, but it still forms a part of the life of manufacturing corporations, and as has often

been said, while competition is the life of trade it is the death of the trader.

Now, my object in speaking to you in this way is to emphasize what I think every speaker has mentioned. We have come as a people to demand legislation of the President of the United States. In the past year I have more than once been surprised that the President did not disclaim responsibility for legislation and place it upon our representatives where, according to our theory of government, it rightly belongs. In this matter we should go to our representatives. We have had the muck-raking articles; we have had the other side, but, except this plain speech by Mr. Doherty and the very active work of the Committee, little has been done in a logical way to instruct our public officials. Still less has been done to instruct the general public. Now, it seems to me that without questioning the motive of the people who have been active for and against us, it is our duty, as individuals and as an organization, to educate that foundation of all activity in this country, public opinion; and more thoroughly and more actively to make our position known to those who represent us in the Government.

The Chairman: The next item on the program is the report of the Committee on Power Transmission Progress, which I will ask Mr. T. C. Martin, our Secretary, to present.

REPORT OF THE COMMITTEE ON PROGRESS*

PART 2

For some years past it has been the practise of the Committee on Progress to include in its report, notes upon the advances made in power transmission, hydro-electric development and kindred subjects. With the creation and growth of the Power Transmission Section of this Association, the desire has quite naturally arisen to treat in that Section all the Convention topics within its scope, and to refer to it all questions arising in the important field that the title of the Section indicates rather inadequately. The program of the present Convention will illustrate, if indeed any such proof were needed, how important to the whole central-station industry the various questions of power transmission, hydro-electric generation, steam plants for large area supply of electrical energy, high voltages, line construction, etc., have become. At the request of Past-President Henry L. Doherty, Chairman of the Power Transmission Section, the Committee on Progress has therefore divided its report this year, for the first time, into two parts, one relating to general development in the art, the other that which is now submitted to the Section. There is obviously a little unavoidable overlapping of subjects, but, if needed, reference can easily be made to Part I of the Report by members of the Section concerned chiefly with Part II.

LEGISLATIVE ASPECTS

In view of the fact that reference will be made in other reports or addresses to the subject, little need be said here about the political aspects of power transmission and conservation. It is impossible, however, not to notice the manner in which these topics have engaged the public attention, the coal miners' strikes on both sides of the Atlantic helping to direct thought and inquiry to a study of the great questions of supplying energy, light and heat. One disadvantage in securing a calm treatment of the subject of water-power has been the tremendous overrating of its value by socialistic agitators and economic visionaries, well exemplified in recent governmental policies adopted in Canada and in attempts to secure radical legislation in New York

* Part I of this Report is presented in General Sessions, and deals with other aspects of the central station industry.

State. The fact that Ontario has embarked on a power-transmission policy that can only bring severe financial disaster to the Province, and that in New York some of the supporters of the proposed measure asserted that the State development of the powers in the Adirondack and other regions would save every dweller there twenty or thirty dollars a year in his expenditure for light, heat and power, shows how wild and dangerous is the talk served up to uneducated ears and minds under the generic name of "conservation." Thus, on March 14 Herbert Knox Smith, United States Commissioner of Corporations, submitted to President Taft a report on the concentration of control over water-power by large interests in important localities. The report recommended that the government should preserve title to the remaining power sites and develop them to prevent their possible monopolization by public utility companies. They should be developed at once, not only to conserve the fuel supply of the country, but also because they were rapidly passing into private control. The public could either develop and operate these sites, selling the energy at market rates, or lease the sites at a rental. Mr. Smith stated that the water-power developed and practically capable of development of this kind probably did not exceed 25,000,000 hp. The total developed water power to-day is about 6,000,000 hp. The total stationary power used in the United States, steam, water and gas, is probably more than 30,000,000 hp. The inquiry was alleged to show that there was concentration of water-powers in three distinct phases: First, there was concentration of control in each important locality; second, large interests influenced some of these local concerns, and finally, there was a growing relationship among large interests. The implication or inuendo was that this is all wrong and an injury to the public, whereas, even if all be true, it is not illegitimate, but laudable, and a public gain. Physical consolidations that unite isolated enterprises in a common network, insuring stability and continuity of supply, are a great benefit and should be encouraged; while they must often, and necessarily, carry with the process a financial consolidation. All that is really needed is to check the overissue of securities, but that again involves its own punishment and cure, and is less and less likely to occur in these days of commission control and regulation.

As a result of the hearings last winter before the National

Waterways Commission, in which the National Electric Light Association participated, a measure favoring the principle of indeterminate franchise was advanced by our body, that principle being, indeed, one supported as to all public utilities by the foremost publicists and economists of the day. In an admirable memorandum submitted by Mr. E. D. Adams, the well-known banker, as a member of a committee of the American Institute of Electrical Engineers, insistence was laid on the essential facts that private capital cannot be invested by legislation and must be attracted by opportunities for profit, security and repayment. The better the security and the assurance of repayment, the more readily will capital be forthcoming at lower rates. Putting aside as unwise and impossible governmental development of the water-powers, Mr. Adams pointed out that the conditions of lease or franchise to private capital must give full confidence in the following ways:

1. By its length of definite term and of the sufficiency of notice of re-entry.

2. By the fairness of its provision for reimbursement of capital expenditure in case of re-entry.

3. By the recognition of the Government (a) that the creation of new industrial and agricultural centers for population requires under most favorable conditions the lapse of several lives for its full development, and that therefore there is necessarily, from the first, a period of uncertainty, speculation and risk for which adequate compensation may be properly sought and acquired; (b) that capital is risked only by opportunity for profit within a comparatively short term; (c) that the Government should await its direct advantages when it avails of its reserved right of re-entry; (d) that an investment under a lease subject to cancellation and re-entry, requires for the protection of the principal, the application of a sinking fund to amortize the capital invested. The longer the fixed term of the lease the smaller the annual charge for the sinking fund, and therefore the smaller the capital charges per annum upon the annual output of water and water-power.

The less the cost of this production, the cheaper it may be sold and the greater the security of the capital in its risks of competition with the other forms of power and fuel, both those now known and those that may yet be discovered.

SOURCES OF POWER FOR TRANSMISSION

Leaving aside these various considerations, most of which for seemingly political reasons have been forced upon a technical and industrial subject, we may note that the coal strike and the higher price of coal have naturally led to a larger consumption of other fuels, such as oil, and have directed attention to many possible economies in that direction. But most startling of all, at the opening of the Smoke Abatement Exhibition in London, on March 23, Sir William Ramsay referred to the ideal state of things that would exist if we had gas retorts in the mines, adding that there was nothing so far as he could see to prevent a bore-hole from being put down until the coal substratum was reached, concentric tubes being used to set the coal on fire by electricity. Air would be blown down to enable the coal to burn as a preliminary operation. Sir William elaborated his idea thus: "When sufficient heat has been engendered, the amount of air sent down can be restricted. Coal with plenty of air gives carbon dioxide. When partially burned it gives carbon monoxide, which is used for gas engines. If steam were blown in, it would give a mixture of hydrogen and carbonic oxide, or water gas, which also is frequently used in gas engines. Bring your gas engines to the mouth of your pit or bore-hole, and produce your power there. You would thus save 30 per cent of the energy of the coal available as against 15 per cent available in fuel engines. That energy might be transformed into electricity at the mouth of the bore-hole and you could distribute it throughout the country, wherever you liked. In this way you would get electricity available for lighting and heating, your railways would be worked by electricity, and the only fuel you would require would be oil for ships."

This is certainly a sensational proposition, going much farther than that of Mr. Ferranti, noted last year, of supplying all England with electrical energy, from plants at the pit's mouth. It is stated that Sir Hugh Bell has placed at Sir William Ramsay's disposition a small stratum in Yorkshire for the purpose of making an experiment. Prof. Arnold, of Sheffield University, regards the scheme as virtually impracticable, and says:

> It is purposed, I understand, to put a bore-hole down with tubes and set the coal on fire. Assuming this to be possible, the first reaction which would take place would be similar to that of preparing coal gas by distillation in

a retort with the production, of course, of gas and coke, which would form a sort of barrier between the air and the unattacked coal.

Even assuming that you got perfect combustion, and got rid of the coke as soon as the combustion had gone on to any extent, the roof above the area where the combustion takes place would fall in and shut off the supply of air to the remainder of the coal. Supposing again that the idea were possible, the shales which now constitute the waste heaps would also be set on fire, and the gas obtained would require washing to remove the very appreciable quantities of sulphuric acid, hydrogen, and the sulphide gases present and the gas would be to a very considerable extent contaminated with the fine dust from the ash and require special washing machinery before it would be fit for the gas engines.

Then there would, of course, always be the danger of very serious explosions. In short, the scheme is virtually impracticable.

It has been pointed out that Sir William Ramsay has been anticipated by a patent taken out here in 1909 by A. A. Betts, of New York, the specification of which reads: "Power gas is generated from unmined coal by starting a fire at the base of one or more shafts or bore-holes, supplying the air and steam through a pipe, and withdrawing the gas through the same or other shafts or bore-holes."

Here it may perhaps be noted appropriately that while for the moment we do not hear so much about energy derived and transmitted from the tides, a contract has recently been closed by the Egyptian Government for a sun machine which, it is reported, will develop thousands of horse-power, and make either a coal mine or a water-power system look antiquated and wasteful. Let us fervently hope it will be a success, for the future of the race depends upon such development of untapped resources.

INTERNATIONAL EXCHANGE OF ENERGY

For some time past we have seen the international exchange of electrical energy along the Niagara frontier, conditions said to apply also on the Pacific Coast with regard to British Columbia, and on the Mexican border, but evidently all the possibilities of the situation are not exhausted. It will be quite interesting to see just what will happen. Applications are now on file in Washington for permission to export from Windsor, Ont., to Detroit, Mich, 25,000 hp of electrical energy from Niagara Falls, some 250 miles away to the eastward, over the transmission circuits proposed by the Hydro-electric Commission

of Ontario. At the same time a Canadian company's application is on file at Ottawa, the capital city of the Dominion, requesting the right to import into Ontario steam generated power from the Delray stations of the Detroit Edison Company, to supply the towns of Leamington, Kingsville, Essex, Harrow and Amherstburg, all about 40 miles distant from the St. Clair River boundary. Although these Canadian towns are almost alongside the proposed location of the Commission's transmission line, Mr. R. S. Stewart, president and treasurer of the companies serving them with electricity, declares that he can purchase Delray power to better advantage than the hydro-electric energy, with which an auxiliary steam plant would be required.

To provide a market for the large block of power necessary if the Windsor transmission is to be extended the remaining 60 per cent of the way from Niagara, the Electric Distributing Company has been organized in Windsor, with a corresponding corporation on the Detroit side, known as the Federal Light and Power Company. From the city of Windsor, in whose behalf the Hydro-Electric Commission would extend its line, the distributing company proposes to purchase 15,000 kw to 20,000 kw, cabling this under the river to the Detroit side, where it is the declared intention to build an independent distributing system, to be operated under the name of the Federal Light and Power Company. It is further suggested that a storage scheme might be employed, enabling the proposed Federal system to enter the general field of power competition in Detroit and to meet the peak loads in excess of the normal rate of transmission. Permission is asked from the United States government to import 25,000 kw. The Burton law which limits the quantity of power that may be brought into this country was recently extended to May 1, and a further amendment is now before Congress, extending the law two years. All of the allowable quantity under this act has been granted in permits issued at Niagara, but it is stated that the full importations thus permitted are not being actually made. The United States government is therefore asked to investigate and revoke permits not so utilized, transferring these rights to the Detroit frontier. According to the promoters of the Ontario enterprise, the necessary Canadian rights have been granted it to proceed to operation and begin construction, and all that is lacking is the United States governmental author-

ity to import power to this side. At a hearing held at Detroit in February for the War Department, to determine upon the advisability of granting this permission, Mr. Alex. Dow contrasted the cost of steam-generated energy in Detroit with that to be expected for the Niagara energy at the rates demanded by the Ontario commission. An estimate of $23 per hp-year, measured on the highest 20-minute demand during each month, was originally given as the cost of delivering Niagara hydro-electric energy at Windsor, but it is likely the commission will require that a margin of profit to the municipality be added to this, in case of re-sale to the distributing company. Although the cost of steam-generated service by the Detroit company is below this, some of the Canadian municipalities in western Ontario, fooled by the loose talk as to "cheap power," have formed the idea that the sale of electricity in Detroit can be made extremely profitable, and these cities are clamoring for a share of the profits following the construction of the western Ontario extension. Although the project was formulated and enlarged upon in Windsor, these neighboring cities now insist on having a part of the returns which Windsor hoped to secure alone.

THE WISCONSIN WATER-POWER LAW

A most important decision protecting the investments of those who develop water-powers has been handed down in Wisconsin, which deserves to be recorded in some little detail. On July 12, 1911, there was approved a Wisconsin law which amended certain sections of the existing statutes relating to the construction and maintenance of dams in or across navigable waters and created new sections of those statutes relating to the granting of franchises authorizing the improvement of navigation and the development of hydro-electric power created by such improvement, and it also provided for a State franchise for the use of water-powers. The law contemplated the repeal of all previous laws granting water-power rights and vested such rights in the State. The right of the State to the use of the power created by the water of streams navigable in any way whatever —that is, even by rowboats or for floating logs—was held to be above that of the riparian owners. The Wisconsin Railroad Commission was instructed to lease water-power rights under

the new law. The purport of the law may be understood by quoting two sections from it:

> No person, firm, association of individuals, corporation or municipality shall conduct or maintain or operate or use any dam or other improvements in or across any meandered or non-meandered stream in this State, navigable in fact for any purpose whatsoever, without having, holding or obtaining a franchise from the State authorizing the construction or maintenance and operation of such dam or improvements.
>
> Any dam or improvements constructed or maintained in or across any such stream in violation of the provisions of this section is hereby declared to be a public nuisance, and the construction of any such dam or improvements may be enjoined or its maintenance abated at the suit of the State or any citizen thereof.

This law affected, of course, all water-power developments in the State, a considerable proportion being used to operate electrical generating plants. A number of water-power owners combined to enjoin the State authorities from enforcing the law, and an early hearing was given by the Supreme Court, as the importance of the innovation was recognized on all sides. Among the plaintiffs were the Wausau Street Railroad Company, the Southern Wisconsin Power Company and the Chippewa Valley Railway, Light and Power Company. On January 30, 1912, a decision was handed down by the Wisconsin Supreme Court, in which its unanimous conclusion that the law was unconstitutional was stated.

While the law had not been enforced, a year's leeway being given to the water-power owners, there is a great feeling of relief over the fact that the law has been nullified. The opinion of the Court was written by Mr. Justice Timlin. It removes from the minds of the managers of many public-service corporations a great uncertainty, and also does away with a menace to the stability and security of existing private investments. Upon the questions involved in the case the Court holds that water-power energy of the water of a navigable river is appurtenant to the private ownership of the banks and bed of the river, subject to the rights of navigation. As the power incident to the falling water is private to the appurtenant property, it cannot be appropriated by the State, either for public or private purposes, except by exercising the right of eminent domain in due accordance with the law. It is pointed out that the long-continued policy of the State in relation to the riparian ownership of water-power rights

has attracted large investments of private capital, largely adding to the wealth of the State and promoting the public welfare. The Court says:

> The large property rights thus created and the great development, with the beneficial results suggested, were accomplished by private enterprise in reliance on the law of the land, particularly the constitutional prohibition against taking private property for public use without rendering just compensation therefor to the owner, and by necessary inference prohibiting the taking of such property at all for private use; also the federal constitutional prohibition against depriving any person of his property without due process of law or denying to him equal protection of the law.
>
> A water-power is composed of the riparian right aforesaid, which is a private possession, and the privilege or franchise to obstruct the flow of water so as to make its natural energy of use, which franchise upon acceptance becomes also private property under constitutional protection as regards interference contrary to the terms of the grant.
>
> In conferring a privilege as aforesaid and acceptance of it there is a contractual arrangement, with a consideration incident, given and received by each party, creating a property right in the privilege itself as an element in the combination of privilege and riparian right forming the water-power property.
>
> So, such a granted and accepted franchise for power purposes, or primarily for navigation and incidentally for such purposes, and the creations in connection therewith, are private property under constitutional protection, in that they cannot be taken by the State for private use at all, and not for public use except by the reasonable exercise of the power of eminent domain.

Farther on the Court says:

> The right of the riparian owner to use the water of a river on his own land up to ordinary high-water mark for the creation of power is unmistakably a private right appurtenant to the land.

PRIVATE PURCHASE OF MUNICIPAL ENERGY

It is well-known that to-day many municipal plants, while not taken over by private systems, secure current from the latter, and the practise grows with the extension of power-transmission networks, which envelop the scattered small municipal plants operating at a real though disguised loss, and supply them with electrical energy far more cheaply than they can possibly produce it themselves. To reverse the proposition of supply is rather unusual, if not unique, but at least one instance may be noted. Last August, under a contract entered into by the Metropolitan Water and Sewerage Board, the State of Massachusetts began the sale of electrical energy for commercial purposes, under a

five-year contract to supply the energy generated at the Wachusett Dam reservoir, Clinton, Mass., to the Connecticut River Transmission Company of Brattleboro, Vt. This is said to be the first instance of a public water supply being used for the development of electric energy to be sold commercially. It was made possible by a legislative act of 1895, which gave the board authority to utilize the fall of water at any dam under its charge for the production of power or electricity and to transmit such power or electricity by pipes, wires or other suitable means, and sell the same, or the right to use such water, by written or other contracts, for a term not exceeding fifteen years. In the present case the Water Board has entered into the contract and it is probable that most of the energy will be used by the Lancaster mills at Clinton, to which it has been resold by the transmission company. The energy will be paid for at the rate of 5.3 mills per kw-hour. The Metropolitan Water Board will draw daily about 100,000,000 gallons from the Wachusett reservoir for the supply of the metropolitan district. This water has a fall of about 90 ft. at the dam. The Legislature of 1908 made an appropriation of $115,000 for the installation of a power plant, and last December the board entered into a contract for the construction of the plant installed in the granite gate-house, consisting of four turbine units of the spiral-case, horizontal-shaft type, direct-connected to 1000-kva, 60-cycle, three-phase generators. Each turbine takes its supply of water from a vertical pipe having an outlet 4 ft. in diameter.

COMBINED STEAM AND HYDRO PLANTS

It cannot be overlooked that in the development of our power-transmission enterprises, there is an increasing combination of the two prime movers, in the operation of the plants, so that in a short time there will be few large urban systems based on steam into which hydro-electric circuits have not been tied. The process appears to be inevitable as a stage in evolution, and it most certainly all helps to clear away that frightful popular delusion that electricity can be got from water-power at practically no expense, "free as God's air," as one mechanical pervert puts it. Our veteran fellow member, President A. C. Dunham, of the Hartford (Conn.) Electric Light Company, who was one of the first to tie-in outside hydro-electric supply with his local steam system, furnished the *Electrical World* last January with

a careful comparison of relative costs. Some of his conclusions seem, off-hand, to be adverse to the majority of hydro-electric power projects. The point is well made that altogether too much value has been set upon average power output from hydro-electric installations, and Mr. Dunham shows what an important part the steam-driven auxiliary is forced to play in practically all cases where the flow of water fluctuates through a wide range at different periods. The plants which are not handicapped by this condition are few and far between, and consequently the minimum power which can be counted upon is the critical factor in the situation wherever the load carried is continuous and of large commercial importance. At the Tariffville station of the Hartford company the cost of operation per kw-hour, including maintenance, is only 0.124 cent, but the cost of supplying the deficiencies of the hydro-electric output by steam-driven machinery is 0.48 cent per kw-hour, making the total unit cost for the year covered 0.6 cent. It appears that hydro-electric power is exceedingly cheap when it is available, but in this case the minimum power developed in any one month, in spite of the use of a reservoir on the Farmington River at Otis, is so much less than the rated capacity of the plant that the installation cannot be inventoried on the books of the company at more than one-third the value given it by some appraisers. In this connection it is interesting to note that the cost of producing electrical energy at the company's turbine plant at Dutch Point, Hartford, reached 0.65 cent in 1910, showing that the steam-driven central station with modern equipment of high power has little to fear from hydro-electric competition except in localities where the cost of fuel is unduly high.

The Southern Power Company has given careful consideration to this aspect of its splendidly developed system, dependent as most flows are in the south on long periods of low water, not altogether compensated for by the still unreservoired devastating floods of the spring. It is desirable, moreover, to plan simple and efficient auxiliary equipment, to tide over the low-water period and to provide reserve capacity in case of a breakdown on the system. This has been successfully done by the Southern Power Company, in whose plants the period of auxiliary operation is generally only two or three months per year, and consequently the fixed charges bear heavily upon the cost of the output

generated by steam. Great simplicity, low cost and convenient location are the three fundamental requirements in auxiliary plants. It is usually found advantageous, as in this instance, to locate the auxiliaries at the receiving ends of the line rather than near the hydraulic power stations, where fuel is more difficult to obtain. On a large system, like that of the Southern Power Company, still another requirement is that the auxiliaries shall not be easily put out of service by the failure of a single transmission line. Hence the wise policy was adopted of subdividing the auxiliary plant and locating it at three points on the network. In ordinary low-water operation, the three steam plants turn energy into the system at or near points of very large consumption, so that the line losses are relatively small. In case of breakdown of one of the long transmission lines, only a portion of the auxiliary plant, at worst, can be put out of service, so that operations can go on throughout most of the system. In carrying out this scheme the Southern Power Company has located in each of the three stations a single great turbo-generator of the horizontal, three-phase type, having a capacity of 8000 kw. This machine is equipped with the ordinary line of auxiliaries and fed with steam from a battery of six vertical water-tube boilers, a type relatively cheap to install and reasonably efficient. The firing is by hand to cut down the relatively large investment and fixed "overhead" charge against automatic stokers. The plant itself is compact and arranged in the simplest possible manner with short runs of steam piping and convenient location of all auxiliaries. The intent was to make it as simple and easy to operate as possible without going to any unnecessary expense. There is thus available a total of 24,000 kw as a protection and reinforcement to the great system, located at three points where it can do the most good.

Steam Transmission Plants

There are under the new conditions a number of steam generating plants that are also in transmission service, several of which were noted last year, that of the Empire District Company, at Joplin, being one of the most notable. Others of equally distinctive character, even if smaller, might be cited, for they adumbrate the new régime when central stations will no longer be restricted to a single locality or a restricted region. For example, in 1909 the Bullock Public Service Company bought the old electric light plant at Missouri Valley, Ia., 3800 popula-

tion, and also the plant at Blair, Neb., 3500 population, 15 miles distant; later the plant at Logan, Ia., 2000 population, and 9 miles from Missouri Valley, was purchased. Because of the smallness of the towns and the adverse conditions under which the older central stations were operated, these plants had never made any money for their owners. They have now been replaced by a modernly equipped central generating plant. A 625-kva turbo-alternator has been installed at Missouri Valley, and 16,500-volt transmission lines built to Logan and Blair, with a 2-mile branch from the Logan line to Magnolia, Ia., 300 population. A number of enterprising farmers who had been operating a gasoline plant built a 2-mile line to connect with the 2300-volt local distribution in Missouri Valley and are now enjoying reliable 24-hour service. At Missouri Valley 2300-volt, three-phase service is used for the local distribution, and at Blair and Logan 1150 volts. Owing to the small demand at Magnolia, voltage is stepped down from 16,500 to 230-115 volts, three-wire, for local distribution. On Sundays the old Blair plant is run and carries the load for the entire system. This keeps the Blair plant in order for emergencies and gives time to clean boilers or make repairs at Missouri Valley.

One of the interesting features of this installation, from an engineering standpoint, is the crossing of the transmission line over the Missouri River near Blair, Neb. As the town is 2½ miles from the river and it is intended to serve other towns near Blair, the main line of 16,500 volts, three-phase, was carried across the river to that town. Two 100-ft. steel towers were used at the river. They were bought with holes punched and sections numbered, and were built up on the concrete foundations. The towers are 20 ft. square at the base, tapering to a double A at the top, 10 ft. wide. A 10-in. by 12-in. by 10-ft. oak cross-arm is fastened to the top "saddle." The towers are double-guyed on three sides to concrete anchors with ⅜-in. galvanized messenger cable. The three cables over the river are spaced 4 ft. apart for the 1200-ft. span and have 30-ft. sag. These cables are seven-strand, ⅜-in. steel, with a heavy copper jacket, and are fastened to double-break insulators at the towers. Guy cables of ½-in. messenger wire are fastened to the other side of the break insulators, and passing over the cross-arm are anchored in concrete set in the ground 200 ft. back from the towers. This construction leaves very

little strain on the towers, except the holding weight of the guys and span cables. A large factor of safety has been provided for all strains. Extra heavy windmill-type towers were used at all railroad crossings, and 30-ft. white cedar poles were set for country lines.

USE OF ALUMINUM CONDUCTORS

The extensive use of aluminum for conductors in high-voltage transmission lines in Canada, as compared with the rareness of its employment for that purpose in the United States, has called for some comment during the past year, and should, perhaps, not pass without reference in this report, in view of one or two new examples furnished from the Dominion. One system furnishes electrical energy for Exshaw and Calgary, Alberta, from the plant of the Calgary Power Company at the Horseshoe Falls on the Bow River, 50 miles west of the flourishing new rival of Winnipeg. With a head of 73 feet, about 9000 kw is now available in three units, and part of this is delivered at 12,000 volts for the shorter service and at 55,000 for Calgary. The main transmission line consists of 40-foot cedar poles, on top of which is a grounded steel cable on small insulators. The three-phase circuit is carried on two cross-arms, the lower an ordinary double arm, the upper an arm extending on one side of the pole only, so that the wires are arranged in a right-angle triangle. The spacing, vertical and horizontal, between wires is 5 ft. 6 in., and the insulators are of the large triple-petticoat variety usual for such a voltage. Seven feet below the lower conductors is a small cross-arm carrying a telephone circuit. The circuit is duplicated over another route. Every tenth pole is double armed and guyed. The poles are spaced forty to the mile, and the construction is certainly one both cheap and effective for a case where independent circuits are desired and the country is relatively clear. The line wires are No. 0 equivalent aluminum cable. As to this use of aluminum, the *Electrical World* remarks: "There seems no doubt whatever that at foreign prices for aluminum it can compete with copper with a very considerable margin of profit. There is a rather heavy duty of 7 cents a pound—equivalent to about 50 per cent—on aluminum imported into the United States and, as is usual in the case of articles carrying considerable duty, the American price is regulated by the duty paid price of the foreign article. Aluminum in

this country is quoted at practically 7 cents a pound higher than the London figure, plus a small allowance of, say, 1 cent a pound to offset a sufficient portion of the transportation charges to make importation unprofitable."

On this subject, Mr. C. B. Smith, of the firm of Smith, Kerry and Chace, contributes some very interesting data and says: "The product made at Shawinigan Falls, Quebec, although produced from alumina shipped from St. Louis, Mo., is sold at a price governed by British competition, and even aluminum rod is now being imported in small quantities and made into wire and cable in Ontario and Quebec mills.

"During the past five years our firm has used aluminum almost exclusively for transmission purposes, except for very long spans, where in some cases copper-clad steel cables are adopted; and if we give due consideration to independent line troubles due to wind conditions, etc., I think it can be fairly said that extreme satisfaction has resulted. I do not think it would be proper here, without consent of the manufacturers, to quote actual prices, but it can be said that there is a large saving in Canada arising from the use of aluminum conductors at the price which we have been able to secure. The Calgary 55,000-volt line cost $2,000 per mile complete, which, considering the high freight rates and long team haul for poles, must be considered very moderate.

"It may be of interest to tabulate the installations of aluminum cable made by our firm since 1907:

Name of Companies, Etc.	Location	Miles of Single Circuit	Voltage	Year Built
Hydro-Electric Transmission..	Western, Ont.	450+	100,000	1908–1910
Winnipeg City.....	Manitoba	154	66,000	1908–1911
Mount Hood Railway & Power Co.....	Oregon	45	57,100	1910–1911
Mount Hope Railway & Power Co.....	Oregon	15	12,000	1910–1911
Calgary Power Co.....	Alberta	47	55,000	1909–1910
Calgary Power Co.....	Alberta	8	12,000	1909–1910
Electric Power Co.....	Central, Ont.	300	44,000	1908–1911
British Canadian Power Co...	Northern, Ont.	48	44,000	1908–1910
Nipissing Power Co.....	Northern, Ont.	22	22,000	1908–1910
Nelson City.....	Southern, B. C.	10	12,000	1909
Approximate Total Mileage Single Circuit.....		1100		

"These lines have required about 3000 tons of cable. The greater variation in sag due to temperature changes is only of importance where long spans are used; and wherever such spans are used it is, of course, necessary to give due consideration to the extra height and cost of towers for carrying aluminum cables. Experience shows, however, that stringing and tying are not more expensive for aluminum than for copper, but rather the reverse. I think that the more experience one has with aluminum cable the better satisfied one is to continue to use it."

The new line for 100,000 volts from Shawinigan Falls to Montreal, which has recently gone into operation, is also built of aluminum, transmission at that pressure having begun last November. The distance is 85 miles, over which the older circuits have been transmitting at 50,000 volts. The line for about 60 miles parallels the tracks of the Canadian Pacific Railway on a 100-ft. private right-of-way, and is approximately 10 miles distant from the company's other lines running to Montreal. The steel towers employed are 70 ft. high and have a 20-ft. base. They carry six 250,000-circ. mil aluminum cables and two 3/8-in. steel cables as ground wires. The towers are spaced 520 ft. apart, and every eleventh tower is a strain tower. Strain towers are also provided at all angles. Electrolytic lightning-arresters are installed at both ends of the lines. At the Ottawa River there are two long spans of 1300 ft., with special towers on each bank.

The Ontario Power Transmission

As the transmission system of the Ontario Hydro-Electric Commission also uses aluminum very largely it may be mentioned next in order. Previous Reports have noted the inception and development of this Government system, which, purchasing electrical energy at the Falls from the Ontario Power Company, at $9.40 per horse-power per year, is already delivering over a large network of 181 miles of 110,000-volt lines and 180 miles of 13,000-volt lines to 29 municipalities, the installed substation transformer capacity being: Toronto, 7500-kw; Dundas, 2250-kw; London, 3750-kw; Guelph, 2250-kw; Preston, 2250-kw; Berlin, 2250-kw; Stratford, 2250-kw; St. Mary's, 2250-kw; Woodstock, 2250-kw; St. Thomas, 2250-kw, and Port Credit, 3750-kw. The circuits have required 2295 standard double-

circuit towers, 335 single-circuit towers, 176 corner and long-span towers, 167 anchor towers and 106 special towers. For the low-tension lines poles of Idaho or Canadian cedar, 40 feet in height, are used. The standard distance between towers in level country is 550 feet. The ordinary spacing of the wires is 9 ft. and the clearance of any line from the steel tower under maximum swing is 3 ft. 6 in., giving a safety distance between lines of 7 ft. The suspension insulators weigh 100 pounds and are in eight sections. With the exception of three miles within the city limits of Toronto, the whole system is of aluminum cable, seven-stranded, with an elastic limit of 14,000 to 15,000 lbs. per sq. in. and an ultimate strength of nearly double this figure. In stringing this cable the tensions were based on the theory that the cables might be stressed to the elastic limit only at the freezing point, with a 3/8-in. coating of ice and a 65-mile wind. For lightning protection the towers are equipped with 5/16-in. galvanized-steel ground wires connected directly to each tower. As many as three are employed on some of the double-circuit towers. The most striking section of the line is the entrance into Toronto with the high-tension circuits, which includes a mile of line 200 ft. off shore in Lake Ontario and a continuation to the substation borne on towers giving 70 ft. minimum clearance between wires and earth. The low-tension distributions, aside from their number and extent, present no extraordinary features, most of them being at the familiar 13,000 volts. The system has now been in operation about fifteen months, beginning with the 100-mile transmission at 110,000 volts to Berlin, Ontario. The Toronto equipment has been in service nearly eleven months.

This is certainly a very interesting system, the engineering of which on the whole appears to have been of a high order. As to the political, economic, financial and social results of the enterprise, it seems far too early to speak, except in terms of caution and doubt. The system has no generating plant of its own, although by some this might be regarded as an advantage, on the principle of the humorist who in paying taxes placed his automobile amongst his liabilities. The commission also is without local distribution plants, transmitting electrical energy merely to municipalities and leaving them at the expense of distributing it among the citizens, an item that must be added in getting the delivery cost. These anomalous facts are all over-

looked and forgotten in the statements made in this country as to what wonderful things are being done in Ontario with what is after all only a transmission system in its earlier stages of trial, and which does not exhibit any feature that could not be paralleled or improved upon elsewhere by plants and systems under private management, where proper conditions of protection to the investment have been permitted by the authorities.

SOME NEW HYDRO-ELECTRIC SYSTEMS

In spite of many adverse conditions and the salutary warning offered at the time of the great panic in 1907 by the financial difficulties of one or two great hydro-electric enterprises, carried on with desperate courage against the threatened collapse in credit, there has of late been a marked revival in hydro-electric development by means of private capital, and a number of plants have been brought to completion or well advanced in construction. In fact, the whole central-station industry is undergoing a readjustment, bringing a great number of older steam systems into relation with exterior sources of hydro-electric supply, and the consequent expansion of the art and industry is of illimitable encouragement and significance. It is not intended here, therefore, nor is it possible to note all the new plants started, or projected, but your Committee entertains the belief that appropriate mention may be made of a typical few.

North Carolina Electrical Power Company

A plant which has quite lately gone into operation is the third installation of the North Carolina Electrical Power Company, of Asheville, N. C., on the French Broad River, 25 miles northwest of that charming city in the mountains. The normal rating of the plant is 5000-hp., and it represents in round figures an expenditure of $500,000, or $100 per horse-power. To find a suitable site it was necessary to raise and rebuild 2.5 miles of the track of the Southern Railway, which skirts the river at this point. The track at the dam was raised 20 ft. higher than the old roadbed, the total excavation amounting to about 60,000 cu. yds., 80 per cent of which was of solid granite. The change in roadbed alone cost $75,000 and required one year to complete. All of the re-location work was done without interference with traffic, although there were operated over this line an average of

from thirty to forty trains per day. The dam is 530.15 ft. long, 30 ft. high, 43.75 ft. thick at the base and 11 ft. at the top. It is built of very heavy concrete, the large stones in some instances representing 5 cu. yds Approximately 22,000 barrels of cement were used in the construction of the dam, the foundation of the power plant and the retaining wall for the protection of the roadbed. The down-stream face of the dam is curved in such a manner as to insure that the water will always cling to the surface and prevent the formation of a vacuum under the falling sheet. In the dam next to the power-house are two circular mud gates, 7 ft. in diameter, which are opened and closed by an electrically driven pump in the power-house. The gates and cylinders are entirely submerged. The four penstock gates are among the largest cast-iron gates made; each gate covers a clear opening of 18 ft. by 7.25 ft. and weighs 13 tons; and they are operated in pairs by an electric motor. There are two 1875-kw, three-phase units, 60-cycle, 6600 volts, with vertical shafts, the exciters being on top of the alternators. For transmission the electromotive force is stepped up to 66,000 volts. Duplicate transmission lines have been built on private right-of-way, one on the west side and the other on the east side of the river, to Plant No. 2 of this company, 6 miles northwest of Asheville, where there is a substation for distributing the energy to Asheville, Canton and other places. The other two hydro-electric plants owned by this company develop 4000 hp, all of which has been utilized in Asheville. This new plant has been made necessary by the increased demand in Asheville and surrounding territory for electric lighting and motor service. The plant was designed by Mr. C. E. Waddell, of Asheville.

Central Georgia Power Company

One of the most notable of the recent hydro-electric developments in the South is that of the Ocmulgee River by the Central Georgia Power Company at Lloyds Shoals, Ga., midway between the cities of Atlanta and Macon, where four streams, the South, Yellow, Alcovy and Tussahaw Rivers, unite the liquid resources of a huge watershed and afford an unusually vast reservoir capacity. The reservoir itself has an area of some 4000 acres, estimated to contain at least 7,000,000,000 cu. ft. of water, and the water has been backed up by its creation for a distance of 15

miles. The dam is 11 ft. wide at the crest, 95 ft. wide at the base, and 1710 ft. between the abutments. It is erected between two high bluffs, which with the riverbed are of solid gray granite. The power-house, which is integral with the dam, is 200 ft. long, while the spillway occupies 728 ft. The power-house is a brick and steel structure, designed for six main generator units of 3000-kw, of which four, at 60 cycles, have already been installed. The voltage of 2300 is stepped up as desired as high as 63,000 volts for the long-distance transmission service over 41 miles to Forsyth and Macon on the south and 18 miles to Griffin on the north. Steel-tower transmission lines are used, the towers being on an average 500 ft. apart. The right-of-way is owned by the company, 100 ft. wide and entirely cleared of standing timber. The Central Georgia Company is, moreover, distinctly a wholesaler of energy, delivering service to its customers at a pressure of 6600 volts in a field where there is a widely diversified industry requiring energy in considerable blocks, for cotton mills, cottonseed oil mills, breweries, flour mills, fertilizer factories, packing plants, brick fields, knitting mills, railway plants, etc.

Recent Work at Coleman, Calif.

The Northern California Power Company has a number of plants in operation, with an aggregate rating of 47,000-hp, supplying energy to 196 miles of 66,000-volt lines and 258 miles of 22,000-volt lines. The oldest plant, the Volta, has an equipment of 8000 hp, operating under a hydraulic head of 1200 ft. To these it has just added its largest plant, that at Coleman, under a head of 480 ft., with an equipment of three 5000 kva, 6600 volt generators, delivering to three 5000-kva, three-phase transformers for raising to 66,000 volts; a fourth transformer being in reserve. The 27,000 hp available is chiefly intended for use in mining and agriculture. The Coleman plant is one of five, and is in fact the lowest of four upon a single stream, Battle Creek. The water for the plant is diverted by a dam, 15 ft. high and only 110 ft. long, into a simple ditch limited on one side by a rubble-basin retaining wall near the dam and then continued through the hard soil. Energy from one of the upper plants was utilized along the line of the canal for motor hoists and for compressors, working hoists and other

machinery. This line was merely brought down to the lower plant and is so constructed that it will become eventually a part of the main transmission line at 66,000 volts. The canal itself is 10.5 miles long from the head works to the forebay, including one tunnel and two long inverted syphons, one of riveted steel pipe and the other mainly of reinforced concrete. The whole drop is concentrated in a comparatively short distance where the contour is such that the water can plunge down quickly for the whole available head. The pipe lines proper in this plant are 3600 ft. long for a head of 487 ft. At the power-house it was desirable to install three units, and, instead of using three pipe lines, just before reaching the power-house a branch of appropriate size is taken from each main pipe, and these two branches are united by a cast-steel Y to the penstock for the third wheel. From each branch, also, is taken a 12-in. pipe for the exciters and each pipe line, therefore, feeds a generator and a half and one exciter, which gives, considering the connections of the plant, a good hydraulic reserve without the added expense of another 3600-ft. pipe line.

Aside from the automatic regulation of the wheels the system is entirely hand-operated. The wheels themselves are turbines fitted with relief valves, while the exciters are driven by impulse wheels with needle regulating nozzles. The whole capacity, 4000 kva, of each generator is taken up by a single three-phase oil-transformer, raising the voltage from 6600 to 66,000, while a spare unit is at hand in case of need. An ingenious feature of the power-house is the method of handling the transformer oil. In the space under the switchboard are two oil tanks, 6 ft. in diameter and 16 ft. long, which can be filled from the power-house floor through manholes. These tanks are connected by pipes to the transformers so that by putting air pressure in the tank from a motor-driven compressor, oil may be forced into any of the transformers or from one tank through an oil filter into another. The circulation of oil for all purposes is accomplished in this convenient manner. The structure of the power-house is simple and cheap, the frame being of steel and the walls of 2-in. cement plaster on expanded metal, forming dense concrete slabs. The roof is corrugated galvanized iron and the gutters, like the walls, are of reinforced concrete. Altogether the whole design of the plant is exceptionally simple and workmanlike, an example of combined efficiency and cheapness.

Utilizing 11-ft. Head

Last year, the Report on Progress gave details of a relatively large plant in Michigan with only a 10-foot head. Prior to that attention was also directed to the 11-ft. head plant at Marseilles, Ill., which was put into operation last October and which supplies energy to half-a-dozen lighting systems, as well as to 125 miles of interurban railway. The Marseilles plant utilizes water from the Illinois River, which was first dammed at that point some forty years ago. Power is still supplied to local industries from the fall thus made available and also to this new plant. The great difficulties in utilizing so low a head for hydro-electric work are the very low speed of the wheels, if the individual wheels are to be of any considerable power, and the regulation, which becomes increasingly difficult as the head falls. There is also very frequently extreme trouble from drowning out the wheels during the times of flood, and extraordinary means have often to be taken to secure anything like uniform speed of the wheels on account of the variable head. In this particular instance the trouble from variable head is less than would be found in many comparable plants. With only 11-ft. head available, large horizontal turbines are practically out of the question, and one is driven to vertical shaft construction. It has been not unusual in such cases to install several turbines with vertical shafts connected with beveled gears to a common driving shaft by which, either directly or indirectly, the generator is driven. In this way it becomes possible to combine several fairly high-speed wheels on a single generator which can then be of normal construction and speed. The objection to this plan is the loss of efficiency in the gearing and a rather excessive amount of space taken. Such construction calls for unusually costly mechanical equipment and a loss of energy in the gears greater than would ordinarily be found in a change of the design in the dynamo to adapt it to lower speed. Foreign practise has gradually drifted away from this construction for hydro electric work toward the use of special very low speed generators, direct-connected to the waterwheel on the vertical shaft. In the Marseilles power-house this later plan of operation has been adopted with admirable results, so far as the newer part of the installation is concerned. The old hydraulic equipment did not lend itself readily to this arrangement and was installed in the new power-house along the old

lines, three 62-in. turbines being geared to a common horizontal shaft driving a single generator, in such groups as fully to utilize the old equipment. The new units are of 320 kva each. The generators are of a typical umbrella type, each directly driven from a 74-in. vertical shaft turbine at 75 r.p.m. One specially interesting feature of the equipment is the means taken to support the weight of the revolving parts, necessarily considerable, since in addition to the runner of the turbine the rotor of the generator is some 10 ft. in diameter. The low head and considerable weight were unfavorable to the use of the ordinary water-step support, and in this case the entire weight of the revolving parts is taken on a carefully designed roller bearing, oil-lubricated, at the top of the umbrella. In other words, the rotor and the runner are hung from a thrust bearing at the very top of the unit, where they can be inspected with the greatest readiness. The arrangement is such that the rotor and, if necessary, the runner can be easily lifted out by the traveling crane. Each individual turbine is controlled by a quick-acting governor, operated by pressure oil and controlled by a push-button switch on the main board, so that the speed of the machines can be very easily adjusted for the purpose of synchronizing.

The transmission is at a line pressure of 33,000 volts, and the poles are of reinforced concrete, there being four outgoing three-phase transmission lines, one of which extends about 20 miles eastward and westward from the plant along the Illinois-Michigan Canal bank, and the other connects with the pole line of the Chicago, Ottawa and Peoria Railway.

The Minidoka, Idaho, Development

The Minidoka project of the United States Reclamation Service takes water from the Snake River at a diversion dam, at which point the hydro-electric plant has been established for pumping and irrigation purposes. Here water is pumped for not less than 48,000 acres, the average lift being 66 feet. The dam is about 50 ft. in height and forms a backwater known as Lake Walcott, which at the head of the spillway crest covers approximately 10,000 acres and holds 53,500 acre-ft. Some 200 miles further up the river is also the Jackson Lake storage reservoir, available at low stage of the river.

The power-house of reinforced granite, 140 ft. long, 50 ft.

wide and 90 ft. high, contains five main generator units of the vertical type, each rated at 2000-hp under heads of 46 ft. from forebay to tailrace. There are also two 180-hp turbine-driven exciters. The generators are 3-phase, 2200-volt, driven by a single Francis turbine, 54 in. in diameter, operating at 200 r.p.m. Each generator is direct-connected to a 3-phase air-blast transformer with a step-up ratio of 2300 volts to 33,000 volts. The transmission system consists of over 38 miles of 33,000-volt line. The circuits are of copper, hard-drawn 3-strand cable, equivalent to No. 5 Brown and Sharpe in cross section, and they are carried on wooden poles 35 to 45 ft. in height, spaced 250 ft. apart. There are three pumping stations.

An Alaskan Plant

It is pertinent to refer here to one of the plants in Alaska that some of the delegates to this Convention are likely to see. It is located at Skagway, which is 1000 miles north of Seattle, and is the terminus of the White Pass and Yukon Railroad, one of the customers of the Home Power Company operating the system. Five hundred feet above the valley in which Skagway lies is Lake Dewey, three-quarters of a mile in length and 700 ft. wide. Nearly 3000 ft. in elevation is the Upper Lake Dewey, 1800 ft. long and 800 ft. wide, feeding the lower lake, which is dammed at both ends. Water is furnished from the lower lake by a 12-in. pipe-line giving a pressure of 215 ft. per square in. on two Pelton wheels, driving a 250-kw alternator and its exciter. From about December 15 to April 15, owing to lack of water, a corresponding plant of steam equipment is used, from five to seven cords of wood being burned under the boilers in a 24-hour run. A low-pressure water main is used in the station for the operation of a waterwheel to which are belted two 0.5-hp, 110-volt generators. These furnish energy for operating the telegraph and telephone lines of the railway company. A small steam engine is provided for use when necessary in place of the waterwheel. A large percentage of the customers have meters and a rate of 10 cents per kw-hour is charged. Flat-rate customers are charged $1.00 per month for each 16-cp lamp. Energy for traction power and lighting is sold to the railroad company at 2.5 cents per kw-hour. A rate of $1.25 per month for each 16-cp street lamp is given to the town.

In the winter time when the lighting circuits are in service for about 18 hours a day the output on them is about 850 kw-hours, but in the summer months when the circuits are in service for only about 12 hours a day with no street lamps in use the output is about 375 kw-hours. The motor load for 10 hours, in the daytime, is about 250 kw-hours for the whole year. Motor service is usually furnished only in the daytime.

PLANTS OPERATING AT HIGH VOLTAGE

The limit of line voltage in power-transmission systems is being steadily raised, until now 100,000 volts has come well within the range of average practicality, while pressures of 11,000, 22,000, 33,000 and even 66,000 may be said to have reached the state of common acceptation as normal and in no way startling.

Practise in the United States

There are now at least half-a-dozen lines operating at or a little above 100,000 volts, and two of them, the Central Colorado Power Company and the Grand Rapids lines, have been in successful operation for some time. The systems of the Great Western Power, the Southern Power, the Great Falls Power and the Central Colorado Power companies, also operate lines exceeding 100 miles of length at approximately 100,000 volts. All have tower lines, with spans from 600 ft. up, and are equipped with suspension insulators and one or more ground wires, grounded at every tower. All have electrolytic lightning arresters in use. The spanning between the conductors varies considerably, from a little over 8 ft. to 15 ft., and even the shortest distance seems to give entire security so far as insulation is concerned. With regard to the performance of the insulators, it has been uniformly good, break-down of the insulation being an unusual occurrence. Up to a recent period the Great Falls plant reported no failures at all, the Great Western Power Company only three or four, and the Southern Power Company only one failure of service during a sleet storm, when some of the insulators gave way mechanically. The first-named plant seems to be particularly fortunate in its insulators, which flash over when wet only at something near 300,000 volts, thus giving a large factor of safety. One of the extraordinary features

reported is the very slight coronal effect observed in any of the plants. The secret is perhaps disclosed by the report from Great Falls, where corona was visible on every live part of the system at first, but gradually became less conspicuous, as if the points of extreme curvature from which corona would naturally start had been gradually worn away. Possibly, however, something may be charged up to increasing familiarity with the phenomenon, so that discharges which would have been immediately noticed at first soon failed to attract attention.

The data here referred to are from reports made to the American Institute of Electrical Engineers last June. With respect to lightning, the Great Western plant has experienced none, and consequently gives no information. The Southern Power Company's system reported 22 shut-downs since January 1, 1910, averaging nearly five minutes of time lost per shut-down. The Great Falls plant reported no shut-downs from lightning, although discharges had taken place over the arresters. The universal experience, however, has been that the 100,000-volt lines suffer no more, and probably less, from lightning than would the ordinary lines at half the voltage. The charging current on these long high-voltage lines is somewhat formidable, running even as high as 6000 kva or 7000 kva. The agreement between the measured and the computed charging currents has proved very satisfactory, so that, although the phenomenon is a very striking one, it is readily prepared for, and on the large systems, which alone can economically use these high voltages, can readily be taken care of by the generators.

Windstorms caused trouble on only one of these system so far as the structure of the circuits is concerned. The lines ordinarily do not tend to swing together, so that practically the service has not suffered. As regards regulation, no trouble had been encountered at any of the plants except such as might be expected on a line of any of the ordinary voltages. In all four of these high-voltage systems, it is apparent that the troubles experienced have been not materially greater than, perhaps not even as great as, one would ordinarily expect on a line of moderate voltage.

At this Institute meeting, Mr. A. O. Austin presented a table showing the design features and operating characteristics of two different 100,000-volt line insulators, one of which weighed 50

lbs. and the other 90 lbs. It was shown that the lighter insulator had greater mechanical strength, greater dielectric strength, greater flashover potential and less depreciation due to the loss of one section. He asserted that for the same cost the cemented type insulator is much more reliable than any interlocking type, for its connections may be tested, thereby eliminating the personal factor. He remarked that practise has shown that unless the

COMPARISON OF 100-kv LINE INSULATORS

	Type *A*	Type *B*
Number of sections	6	4
Number of shells per section	1	2
Diameter, inches	10	14½
Length of insulator, inches	34½	41
Mechanical strength, pounds	10,000	8,000
Weight of porcelain, pounds	30	62
Total weight, pounds	50	90
Number of cemented joints	12	12
Formation of arc—dry	Through air	Over surface
Formation of arc—wet	Through air	Over surface
Total tested dielectric strength, kv	540	440
Minimum to maximum width of leakage path in per cent	16	10.6
Wet flashover	265	235
Depreciation due to loss of one section, per cent	16 2/3	25

interlocking parts are large the arc punctures may destroy the connections, because the interlocking connections do not always come into contact. Reliability in practise depends on the testing of insulators and connections, in order to eliminate any weak part. High mechanical strength is obtained by making the gripping surfaces effective and developing the full shearing strength of the cement, thus permitting the use of very small metal parts. The electrical advantages of scientific design are greater dielectric strength, higher surface insulation and lower depreciation. The economical advantages are lower cost of production, lower weights and lessened length.

110,000-volt Line in Germany

So far as can be ascertained, the first line in Europe to operate at a voltage exceeding 100,000 is that at Lauchhammer, Germany, which for a transmission of 35 miles has gone up to 110,000 volts, while an interesting fact about it is that the plant is steam-driven and uses coal at the pit's mouth. The initial equipment consists of two 5000-kw turbo-generators, delivering

energy at a voltage of 5000. The line voltage used for so short a transmission is due first to the fact that the ultimate energy will be some 20,000 kw, and second, to the question of standard accessory apparatus, including transformers. Any voltage over 65,000 required special design, and so having determined in the interest of economy to go above this figure they apparently decided to play the limit. From the generating plant the energy goes at 5000 volts to the switch-house. Duplicate bus-bars are provided, connected with the raising transformers, which themselves feed into duplicate 110,000-volt bus-bars. Disconnecting switches and oil switches are installed on both sides of the transformers and also on the outgoing high-tension transmission lines. The transmission line consists of a duplicate system of 3-phase conductors carried on a single line of iron towers. Three cross-arms are provided, the one at the top of the tower being arranged to carry four wires with the outer ends of the cross-arms turned down so as to bring the outside wires on either side of the tower in position to form an equilateral triangle with the two others of the circuit, carried respectively on the upper cross-arm nearer the tower and at the end of the short lower cross-arm. All wires are carried on 5-disc suspension insulators. There are thus two complete circuits, one on each side of the tower, 5.9 ft. between centers and completely transposed once a mile. At the extreme top of the tower is a 100,000 circ. mil steel cable grounded, and serving to help in anchoring the towers and to protect against lightning. In addition, the third and lowest cross-arm on each tower carries a bow-shaped guard under each one of the circuit wires, on which, if the insulator should break, the wires would be instantly grounded. In other respects the construction is quite similar to that of American high-tension systems, and an American automatic regulator controls the voltage in the power-house. The tower line impresses one as being neater, lighter and probably cheaper than the ordinary construction in this country. The base is only about 27 in., so that the structure resembles a latticed pole rather than a typical tower, and is possessed therefore of a certain flexibility which is of use in case a wire breaks. The line crosses the River Elbe at one point. The circuits are of 7-strand hard-drawn electrolytic copper, 83,000 circ. mils cross-section; the spans are from 500 to 650 ft., and the height varies from 60 to 65 ft. Besides being

connected through the 110,000-volt line, the substations at Gröditz and Riesa are connected by a 60,000-volt line covering the districts served by these stations.

140,000-volt Line in Michigan

One of the papers to be read before the Power Transmission Section will deal with phenomena witnessed on the 140,000-volt line by means of which the plant of the Au Sable Electric Company furnishes electrical energy to Bay City, Saginaw and Flint, Mich. This is the highest voltage that has so far been achieved on long-distance power circuits, and is a present culmination of the work of the Commonwealth Power Company of Michigan, which has "hit it up" from 72,000 to 110,000, and now to 140,000. The present 125 miles of 140,000-volt line has already been in successful and uneventful service three months, and on test has been carried to a potential of 145,000 volts measured at the power-house, with a corresponding pressure at the substation end of 170,000 volts, due to the condensive reactance of the long line. The conductors are supported on suspension insulators composed of ten 10-in. discs, each disc tested to withstand 80,000 volts continuously or 125,000 volts momentarily, and all high-tension insulation and clearance are designed with a wide margin of safety beyond the normal 140,000-volt operating potential. Special designs of standard high-voltage equipment were required to meet the 140,000-volt conditions for oil switches, lightning arresters and transformers. The three last-mentioned units have their high-tension windings delta-connected, imposing the full 140,000-volt pressure across the coils, and in several cases transform down, in a single step, to minor 370-volt secondaries, a ratio of nearly 400 to 1. Over the 140,000-volt line, hydro-electric energy from the 9000-kw Cooke plant, developing a 40-ft. head on the Au Sable River in the wilds of Iosco County, is now being transmitted 85 miles to the Zilwaukee substation, which supplies Bay City and Saginaw, and 40 miles further to Flint, where with a steam-turbine auxiliary a large industrial load is served. The Cooke development is but the first of several water-power sites on the Au Sable River whose output will be delivered over the new transmission line. A second site at Five Channels, 8 miles above Cooke, is now under development and will be operating before the close of the year.

By June the 140,000-volt transmission will be in use as far as Owosso and Lansing, later tying-in to the associated transmission systems at Battle Creek, a distance of not less than 250 miles from the power site on the Au Sable River.

The line is carried on steel galvanized towers of the tripod construction of 40 ft., 50 ft. and 60 ft. on the lowest conductor, spaced about 500 ft. apart. Two conductors are carried on one side of the tower and one on the other, each supported by a string of 10-in. disc insulators occupying a vertical space of 5 ft. 3 in. The two conductors on the same side of the tower are 12 ft. apart vertically, while the other two sides of the triangle are 17 ft. 4 in. The conductors themselves are No. 0 equivalent, medium hard-drawn stranded copper, and under ordinary conditions seldom show coronal discharge even at the full working pressure of 140,000 volts. The charging power required is about 80 kva per mile, and when the receiving transformers are disconnected the open line carries about 3000 kw dissipated as coronal and leakage loss in one form or another as the voltage rises. Load at the receiving end may actually diminish the line current as the power-factor moves toward unity. An article in the *Electrical World* of April 20, 1912, says: "With 140,000 volts on the generator and the Flint transformers connected but not loaded, pressures 17 per cent higher, or nearly 164,000 volts, are read at Flint, due to the capacity reactance of the line. With the receiving transformer primaries disconnected, the end voltage of the open line probably rises to 190,000 volts, although no measurements have been taken. Of course, the excessive rise above the corona point in the distant sections causes leakage losses in those portions which may run quite high. With receiving transformers disconnected, the open line is found to consume or leak about 3000 actual kw, dissipated as corona loss in the distant sections when the voltage is high. With additions of load at the receiving end the line current remains practically the same or even diminishes, depending on the inductive character of the demand, while the power-factor, of course, rises. With a 4000-kw 65 per cent lagging inductive load at Flint, the power-factor at the generators has been observed to be 85 per cent leading. With accession of further inductive load and the completion of the Owosso link, it is expected to be possible to move the point of unity power-factor back to the generating station. No tests

have thus far been made on the corona power loss of the line running at normal 140,000-volt pressure, but this loss is believed to amount to about 3 kw per mile. The transmission is designed to convey about 25,000 kw, and as the point of economic loading is approached its condensive reaction will be offset, a more uniform voltage maintained from end to end, and its efficiency increased. Like any large piece of apparatus, a 140,000-volt line must be operated within the magnitude of its capabilities."

SOME COMING POWER-TRANSMISSION PLANTS

It is encouraging to find that as the outlook of the financial world takes on a brighter hue, and that as the courage of the investor returns, there is an increasing disposition to assist in the development of hydro-electric enterprises. This is the more significant in view of the fact that the profitable returns from such plants have hitherto in the aggregate and in most individual instances been so small, and that the profit lies largely in the future. Meantime the investor has the satisfaction of knowing that with his help, real conservation is going on, and that unlike some mock conservationists, he is not tying up resources that mankind needs, but unlocking them for use now and for all time.

The Great Plant at Keokuk, Ia.

References have previously been made to the great enterprise of the Mississippi River Power Company, which is now creating a power plant on the river at Keokuk, Ia., where the power station will have an initial rating of 150,000-hp, with an ultimate rating of 240,000-hp, and will, it is said, when completed represent a total investment of $25,000,000. The dam will be 4600 ft. long across the river from Keokuk to Hamilton, Ill. In a recent lecture before the Western Society of Engineers, Mr. Hugh L. Cooper, chief engineer of the development, said that in view of the recent failure of dams in Pennsylvania and Wisconsin, it was important to take very careful precautions in making the foundations for the main dam at Keokuk. At distances of 36 ft. test holes have been driven to a depth of 36 ft. in the bedrock of the river in the middle line of the 4600-ft. main dam. Compressed air is forced down one hole and if there is any indication of escaping air or mud in the adjoining hole further excavation is made to discover the cause. The rock in

the bed of the river is excellent for foundation work, and in only one instance had a defect been discovered by the careful testing adopted. This was a stratum of 4 in. of clay about 4 ft. below the surface, and the excavation was carried down below this weak spot. The extire development at Keokuk will cost about $25,000,000. The interest charged on the money secured to carry on the work is nearly $3,000 a day, so that the necessity for all reasonable haste is obvious and great pains have been taken to expedite the construction work as greatly as is consistent with safety. About 1500 men have been employed on the job. The damages paid for lands which will be overflowed by the lake created by the dam amounted to about $2,000,000. This lake will have an area of nearly 100 sq. miles, but will be of small value as a storage reservoir, because the development is a low-head and the greatest necessity is to maintain a uniform head of water so that the storage supply cannot be drawn upon to a very great extent.

One contract has been entered into to supply 60,000 hp of electric energy to the public utilities of St. Louis, 140 miles away. This contract is very elaborate. The base rate made for electrical energy delivered in St. Louis is $18 a hp-year at 60 per cent load-factor. However, by an interesting provision, it is agreed that there shall be a revaluation every ten years, made by arbitrators, if necessary, to fix anew the rate for electrical energy according to the fluctuation in the market price for coal for the average of a term of two years before the date of revaluation. The base rate for coal is taken as $1.42 a ton. For each increase or decrease of 1 cent in the price of coal a corresponding increase or decrease of one-half of 1 per cent shall be made in the price of the hydro-electric energy. Thus, if in ten years the price of coal has gone up 20 cents a ton, the price of the energy delivered in St. Louis will be advanced 10 per cent, making it at that time $19.80 a hp-year. Similarly, a reduction in the price of coal will mean a reduction in the price of electricity under the St. Louis contract, which is for a term of ninety-nine years.

The 7500-kw generators, of which fifteen will form the initial installation, will be probably the largest hydro-electric units in existence using one runner in the turbine. The rotor of each of these units weighs about 500,000 lbs.

A Million-Horse-Power Plant for Canada

One of the projects that has recently dazzled the world comes from optimistic Canada, and proposes to absorb 1,000,000 hp from the great St. Lawrence Rapids. According to the published reports, England may supply much of the $100,000,000 capital needed to create this plant. A recently incorporated concern, called the Eastern Canada Power Company, proposes to generate the amount of power stated within 25 miles of Montreal, and contemplates the use of the water which dashes through the Coteau Cascade, Split Rock and Cedar Rapids from Lake St. Francis to Lake St. Louis on the St. Lawrence River. The authorization of the government must be obtained before work can be commenced, but the new government has already approved of the plans of the Cedar Rapids Power Company. It is said that another corporation, the Eastern Canada Power Company, will probably absorb the smaller one and the two concerns work co-operatively. The new leader of the Unionist party in the British House of Commons, Bonar Law, has, it is said, a large interest in the venture; so has Sir Max Aitken, in whose brain this giant scheme originated. Should a million horse-power be thus generated near Montreal, it will be very interesting to see how it can be utilized.

The Lakes-to-the-Gulf Project

At the luncheon of the Electric Club of Chicago on January 3 Mr. Isham Randolph, who has paid particular attention to waterways and who was chief engineer for the Sanitary District of Chicago for several years during the period when the Chicago Drainage Canal was under construction, spoke on "The Lakes-to-the-Gulf Deep Waterway." He said the Chicago Drainage Canal was the largest artificial waterway in the world when it was completed, but it will soon be overshadowed by the great Panama Canal. Its channel now connects the South Branch of the Chicago River in Chicago with the Desplaines River at Lockport, Ill. There is thus a deep waterway in existence connecting Lake Michigan with one of the tributaries of the Illinois River and so with the Mississippi River and thus to the Gulf. For several years there have been zealous advocates of the plan of deepening the Desplaines, Illinois and Mississippi Rivers so as to make a waterway connecting the Great Lakes and the Gulf of

Mexico and having a uniform depth of possibly 14 ft. From Lockport to Utica, Ill., the latter place being the present head of navigation on the Illinois River, is a distance of 62 miles, and there is a drop of 100 ft. in this distance. It is proposed to construct a channel in or adjacent to the Desplaines and Illinois Rivers to connect these two points. Such a channel would have several locks and a minimum width of 300 ft., with a proposed depth of 14 ft. There are four sites where water-power might be developed, and the net head for all four of the sites is 88 ft. With 14,000 cu. ft. of water per second flowing through this waterway, Mr. Randolph has calculated that about 105,000 net electrical horse-power could be developed at the four sites available.

New Development in Oregon

The State of Oregon has already witnessed some splendid hydro-electric development. Two new hydro-electric power companies, La Tourelle Falls Power Company and the Coast Range Power Company, have recently been organized to utilize the water-power of lower La Tourelle Falls and the Nehalem River, Oregon. The plant of the former company will be located at the foot of La Tourelle Falls and will utilize both the upper and lower falls, which will aggregate a head of about 500 ft. The first installation will comprise two 200-kw, 6600-volt, 3-phase, 60-cycle generators, and the energy will be sold to the town of La Tourelle and vicinity. The Coast Range Power Company will utilize the falls at the Nehalem River, below the mouth of the Salmonberry River, where it is planned to install two 750-kw turbo-generator sets. Energy will be developed at 6600 volts and 60 cycles, which will be stepped up to 44,000 volts and transmitted to Fillamoak, Ore., and to the Tualatin Valley.

Plans are being made by the Pacific Power and Light Company for extensive hydro-electric developments in the Columbia River at Priest Rapids, southwest from Spokane, and the ultimate capacity of the system will be 1,000,000 hp. The cost of the project is estimated at $6,000,000 to $10,000,000 and the work of construction will take over six years for completion. Advices state that a dam will be constructed at the foot of the rapids, to have a height of 75 feet, which is the drop

of the river in nine miles. The plans include further work on the Hanford irrigation project owned by the company and also the building of a distribution system for supplying energy to the eastern portion of the State of Washington.

Announcement is also made that the Lewis County Power Company has been incorporated in Idaho to develop about 100,000 hp on the Salmon River, at a cost of $3,000,000. The power site is the same as that located by the Lewiston and Southern Electric Railway Company several years ago, when it planned to build an electric road between Lewiston and Grangeville. The initial plans call for the driving of a 4000-ft. tunnel through a narrow ridge, which will provide a fall of 200 ft., affording capacity for a first development of 40,000 hp, and this will be increased later on by the driving of a second tunnel or enlargement of the first one.

Plant Ordered for Idaho

Contracts have been awarded for the equipment to be used on the Crane Falls power and irrigation project, Idaho, as follows: Three quadruplex open-flume-type hydraulic turbines, each of 3000 b.hp capacity, under a 27-ft. head, at 164 r.p.m.; two single-runner exciter turbines, each of 215 b.hp capacity, under a 27-ft. head, at 350 r.p.m.; three waterwheel-type 3-phase, 60-cycle, 6600-volt alternators, at 164 r.p.m., and two 120-kw, 125-volt compound-wound exciters, at 350 r.p.m. Contracts have also been placed for equipment for the same project as follows: Three single-phase, 60-cycle, 6600-volt to 66,000-volt high-tension step-up transformers; three single-phase, 60-cycle, 60,000-volt high-tension to 2200-volt low-tension step-down transformers, and three 1025-hp, 865-r.p.m., two 700-hp, 700-r.p.m., two 330-hp, 495-r.p.m. and two 255-hp, 1150-r.p.m., 3-phase, 2200-volt induction motors, with squirrel-cage secondaries and complete starting equipment.

A Big Development in Vermont

Interests associated with one of the Connecticut River power companies are promoting a hydro-electric project on the Deerfield River in Vermont, the initial development of which, it is reported, will approximate 25,000 hp. It is planned to dam the river at several places near Shelburne Falls, Vt., and to construct a reservoir at Somerset, Vt., where water will be

impounded to a height of 100 ft. and over an area approximating six square miles. An underwriting agreement for the issuance of $3,000,000 5-per cent 40-year gold bonds and $750,000 6-per cent cumulative preferred stock was effected in Boston recently. The ultimate expenditures, it is stated, will aggregate $12,000,000.

Various Plans for the South.

A number of hydro-electric schemes are materializing in the South, but mention can only be made of a few of them here. Plans are being carried forward rapidly for the formation of the Little River Power Company, which will supply energy throughout the northern part of Alabama. The construction of three water-power developments, having a total rated output of 150,000 hp, is contemplated. The first of these will be on the Little River, near Fort Payne, Ala., and will have a rating of 50,000 hp under a head of 590 ft. Energy will be transmitted from this plant at 100,000 volts to Anniston, Gadsden, Huntsville and neighboring localities.

The organization of the Dix River Power Company, which will build a large hydro-electric plant on the Dix River, Kentucky, near its confluence with the Kentucky River, has been practically completed. The company expects to spend $3,000,000 on its plant, which will generate 24,000 hp, and on the construction of transmission lines to Louisville and Lexington, Ky., and Cincinnati, Ohio, as well as to smaller towns near by, such as Stanford, Harrodsburg, Lancaster, Nicholasville and Danville. A feature of the construction will be a 200-ft. concrete dam across the river near Danville.

The formation of the Tennessee Railway, Light and Power Company, with a total authorized capital and bonds of $120,000,000, points to a huge hydro-electric development to serve large portions of Tennessee and Georgia. The Tennessee Power Company will own, free from all encumbrances (other than its first-mortgage bonds), the following properties: The 20,000-hp hydro-electric plant on the Ocoee River at Parksville, Tenn., now in operation; the transmission lines now in use from this plant, by way of Cleveland, to Chattanooga; the transmission line from Cleveland to Knoxville, Tenn., which is nearly completed; the transmission line from Cleveland southward to the Georgia State line; the Great Falls power site and reservoir at the junc-

tion of the Caney Fork and Collins Rivers, near Rock Island, Tenn., capable of developing 80,000 hp, and said to be the most desirable water-power site in Tennessee; two additional sites on the Ocoee River, in addition to the first-named above, one capable of developing 16,000 hp and the other 30,000 hp. The following construction work will be undertaken immediately by the company: An addition of 15,000 hp to the first development on the Ocoee River, now in operation as above; construction of a 16,000-hp hydro-electric plant on the second site on the Ocoee River, to operate under a 250-ft. head; construction of additional transmission lines from Parksville, by way of Great Falls, to Nashville, Tenn., and from Nashville through the surrounding country, to reach the various power users.

Large Work Abroad

This country is not alone in such courageous grappling with large possibilities, and several developments abroad might be noted. It will suffice to mention two as typical. It is reported that the government at Brazil has granted a concession to firms in London and Rio de Janeiro, for the development of the water-power of Paulo Affonso Falls on the San Francisco River. The concession is for a period of seventy years, and it is required that an initial plant of 200,000 hp shall be installed, to be increased to 1,300,000 hp fifteen years after the primary installation. Another case is that of the Inawashiro Hydro-Electric Power Company, of Japan, which is building a generating plant of an initial capacity of 75,000 hp, whose energy is to be transmitted at 110,000 volts to Tokio, 145 miles away.

The Chairman: The next paper on the program is "Switchboard Practise for High-Tension Power Transmission," prepared by Mr. Stephen Q. Hayes, Pittsburgh, Penn.

SWITCHBOARD PRACTISE FOR HIGH-TENSION POWER TRANSMISSION

Power transmission has played a very important part in the development of the electrical industries, and the switching equipment that provides for the proper control and protection of the high-tension circuits is one of the important elements entering into the success of high-tension power transmission. A paper on this subject may act as a nucleus for the presentation of the opinions of engineers, operators and managers, and may serve to start a discussion of great value and interest.

The question of switchboard practise will be considered under the following headings, for the sake of simplicity:

1-A Switchboards—General Features.
1-B Switchboards—Panel Type.
1-C Switchboards—Pedestal Type.
1-D Switchboards—Desks or Bench Boards.
2-A Apparatus—General Features.
2-B Apparatus—Exciter and Field Control.
2-C Apparatus—Oil Circuit-Breakers.
2-D Apparatus—Disconnecting Switches.
2-E Apparatus—Lightning Arresters and Choke-Coils.
3-A Station—General Features.
3-B Station—In-door Design.
3-C Station—Out-door Design.

1-A SWITCHBOARDS—GENERAL FEATURES

In designing the switchboard equipment for any installation, it is necessary to carefully consider the relative values of flexibility and simplicity, and to balance up the cost of apparatus needed only in an emergency against the loss that might occur if provisions were not made for such a contingency.

In most high-tension, large-capacity, modern plants the main alternating-current circuits are controlled by electrically operated oil circuit-breakers, and electrical operation is often used for the field rheostats, field switches, governor motors, etc. The controllers or switches for operating this apparatus, together with the meters for indicating and recording the current voltage, etc., in the various circuits, are mounted on a switchboard of the panel

type, on pedestals or on control desks, depending upon individual taste and local conditions.

For switchboard panels, pedestals, desks, etc., the material employed is usually blue Vermont marble or slate with either oil or marine finish. Owing to the difficulty of matching polished Vermont marble and removing oil stains, scratches, etc., marine or oil-finished slate is usually considered the best material for switchboards.

1-B SWITCHBOARDS—PANEL TYPE

Where these are used it is customary to mount the equipment of instruments for the generators, transformers, feeders, etc., on the same panel with the controlling devices.

Figure 1 shows one of two halves of a panel switchboard recently furnished for the Nisqually generating station of the City of Tacoma municipal plant for the control of two 220-kw, 125-volt exciters; four 5000-kva, 6600-volt, 3-phase generators; four banks each of three 1667-kva, single-phase transformers; two 10,000-kva, 57,000-volt, 3-phase feeders, and various local circuits. This switchboard comprises fourteen panels of blue Vermont marble mounted on angle-iron framework and arranged for the control of the various circuits by means of electrically operated switches, circuit-breakers, rheostats, etc. The instruments in the alternating-current circuits are operated from current and potential transformers, and suitable jacks are provided to permit the calibration of the various meters without removing them from the switchboard. The two exciters connect to a common field bus and are controlled by a Tirrill regulator. The four generators connect to a low-tension bus supplying current through step-up transformers to a high-tension bus which in turn feeds the transmission lines. Both the low-tension bus and the high-tension one are sectioned at the middle by means of non-automatic oil circuit-breakers.

1-C SWITCHBOARDS—PEDESTAL TYPE

This type of control is used in certain transmission plants where it is considered advisable to have the switchboard equipment for each generator a practically independent unit, and in this case the necessary control devices are ordinarily placed on a suitable pedestal, and the instruments are mounted on a framework or post near the pedestal.

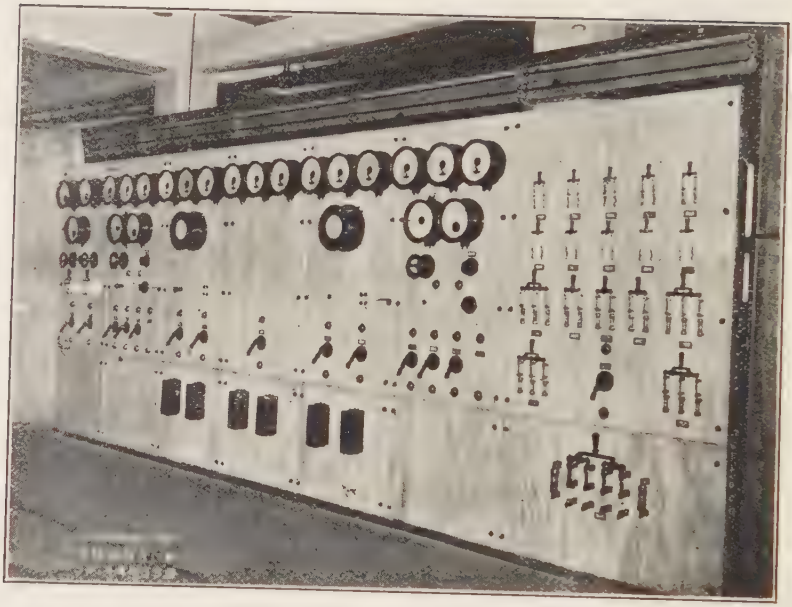


FIG. 1—PANEL SWITCHBOARD, NISQUALLY PLANT, CITY OF TACOMA

FIG. 2—OPERATING ROOM, ONTARIO POWER COMPANY

Figure 2 shows the operating room of the Ontario Power Company with seven main control pedestals and main instrument posts in place at the time this photograph was taken. At that time the switching equipment installed in this control room took care of seven 8700-kva, 12,000-volt, 3-phase generators with banks of 3000-kva transformers stepping-up to 60,000 volts. Each of the seven generator control pedestals is equipped with push-button control for the generator field circuit, and is provided with a white signal lamp that lights up when the field-circuit is closed. A miniature bus is placed on the control pedestal to show the connections made by the various oil circuit-breakers in the generator and transformer circuits that permit connecting the generator circuit to either of two sets of busses or to the low-tension side of the bank of three 3000-kva, step-up transformers, the high-tension side of these transformers being controlled by another oil breaker. In addition to the controllers and indicating lamps for use with the oil circuit-breakers, other controllers are provided for the field rheostat and for the governor motor. Suitable synchronizing lamps and receptacles are also placed on these pedestals.

It may be noted that each of the generator control pedestals has mounted on it a field ammeter, and back of the control pedestal is located an instrument post. Each of these posts is provided with a single-phase synchroscope, a frequency meter, a 3-phase power-factor indicator, transformer and generator meters, indicating wattmeters and similar instruments. The base of the instrument posts contains a number of calibrating jacks that permit the calibrating of the instruments without removing them from the post.

The two pedestals in the center of the room are used for the control of the exciters with their Tirrill regulator equipment, while the panel-board controls a number of 60,000-volt out-going circuits supplying power to Syracuse, Rochester, Buffalo and other places.

On the floor directly below the operating room panel-boards are installed containing full equipments of graphic recording meters, watt-hour meters, etc., while on the basement floor are installed other panels containing the overload relays, and the terminals of all of the multiple conductor cables connecting from the controllers to the breakers, field switches, rheostats, etc., and

from the instruments and relays to the current and potential transformers.

1-D SWITCHBOARDS—DESK TYPE

Where it is desired to reduce the length of the operating board to a minimum, it is customary to install a control desk and to mount on it various controllers for use with the circuit-breakers, field switches, field rheostats, etc., and to locate the instruments for the various circuits on an independent instrument frame, arranging this frame at such a height that the station operator standing at the control desk can look over the top of the desk and under the bottom of the instrument frame out into the station to readily observe the operation of the machine which he expects to control.

Figure 3 shows the control desk and instrument frame recently supplied for the generating station of the Mount Hood Power Company. This desk is made of marine-finished slate on a pipe framework, and the four sections now supplied control 150-kw, 125-volt exciters; 3750-kva, 6600-volt generators; six 3750-kva step-up transformers; one 21,000-kva, 57,300-volt transmission lines, and various local service circuits. A complete miniature bus system has been placed on the desk to show the connections made by the various breakers, and card-holders are supplied to contain the names of the various circuits. The instrument frame contains a complete equipment of ammeters, voltmeters, power-factor meters, indicating wattmeters, etc., for the generators, exciters, transformers and feeders, all of these meters being 7 in. diameter, the alternating-current meters having scales 14 in. long and the direct-current meters scales 7 in. long. The station instrument post contains voltmeter, frequency meter and synchroscope of the same design, as well as an automatic synchronizer which connects in the various generators only when they are running at the correct speed, developing the correct voltage and are in synchronism with the system.

2-A APPARATUS—GENERAL FEATURES

In power plants for high-tension transmission, distant control apparatus is usually resorted to, and some auxiliary source of power (such as electrical operation) is employed, because of the physical exertion necessary to manipulate large apparatus, the

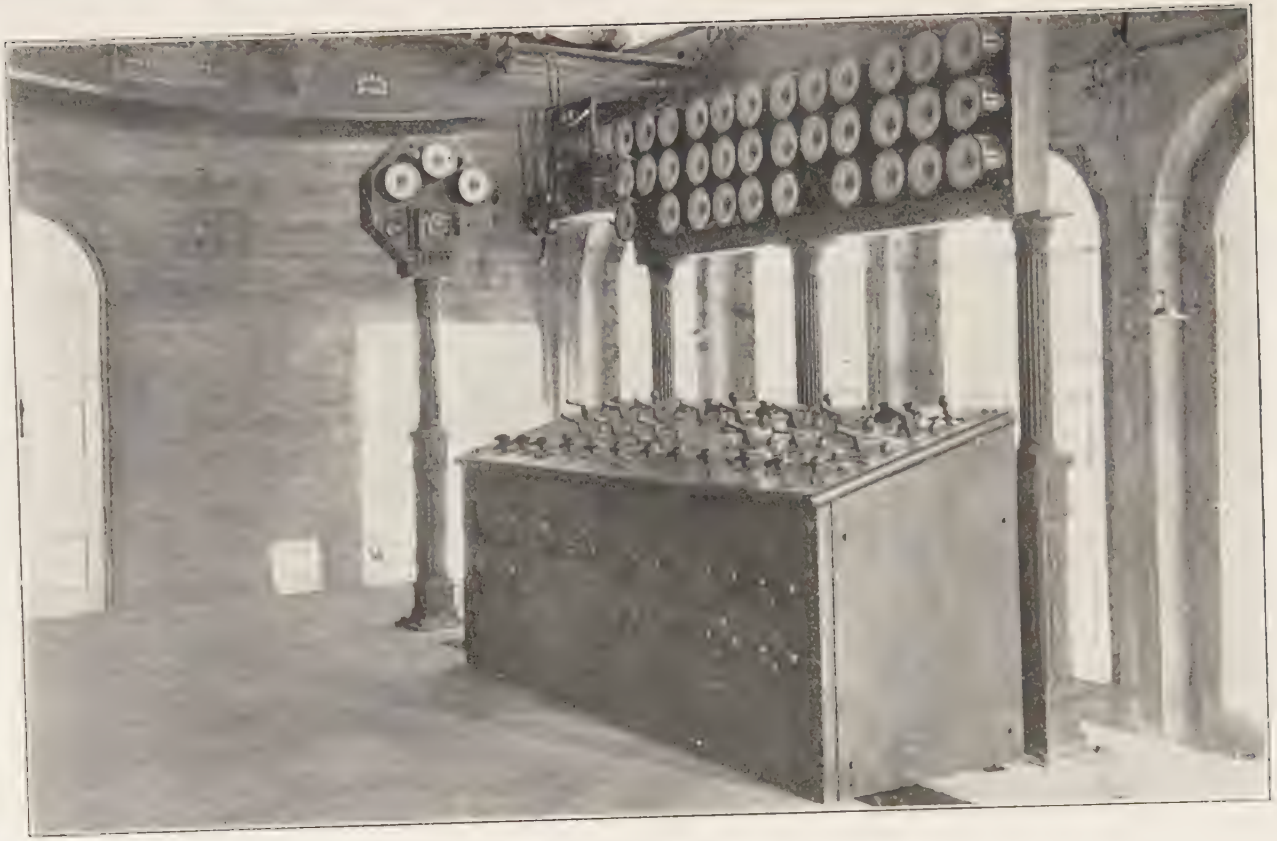


Fig. 3—Control Desk, Mt. Hood Power Company

number of circuits to be controlled, the high voltage used and the advisability of concentrating the control of widely separated apparatus and for other important reasons.

Where distant mechanical control is employed, American practise usually prefers the use of bell cranks and rods, although wire rope or chain passing over pulleys or sprockets can frequently be employed to advantage for certain apparatus.

With any system of distant-control apparatus it is necessary for the operator to know whether the different pieces of apparatus are actually closed or opened or have performed the function assigned to them, and various indicating devices are used. The device most frequently employed consists of red and green indicating lamps, one of which is lit to show when a breaker has been closed, and the other to show when it has been opened. The lamp indicators are usually arranged to form part of the miniature bus-circuits, to show the connections made by the various switches.

2-B APPARATUS—EXCITER AND FIELD CONTROL

For the electrical control of exciter circuits, it is usual to employ solenoid-operated, carbon-break, circuit-breakers, these being mounted on panels which also contain the solenoid-operated or motor-operated field rheostats, and these panels are usually combined with similar panels containing electrically operated field switches and the electrically operated field rheostats for the generator circuits, in the manner shown in Figure 4, this being the exciter and field switchboard for the generating station of the Olympic Power Company at Port Angeles, Wash. The circuit-breakers in the exciter circuits and the field switches in the alternating current generator field circuit are standard, carbon-break, non automatic circuit breakers, with laminated copper brush main contacts and carbon auxiliary contacts, these breakers being operated by means of direct-current solenoids. Each breaker is provided with a double-contact push-button, depressed by the brush, so that when the breaker is closed or released the double-contact push-button operates signal lamps on the control desk. The field switch is provided with the usual field-discharge resistance.

The motor-operated field rheostat face-plates are provided with clutches, so that, in case of trouble to the motor, the face-plate may be operated by hand after disengaging the clutch. With

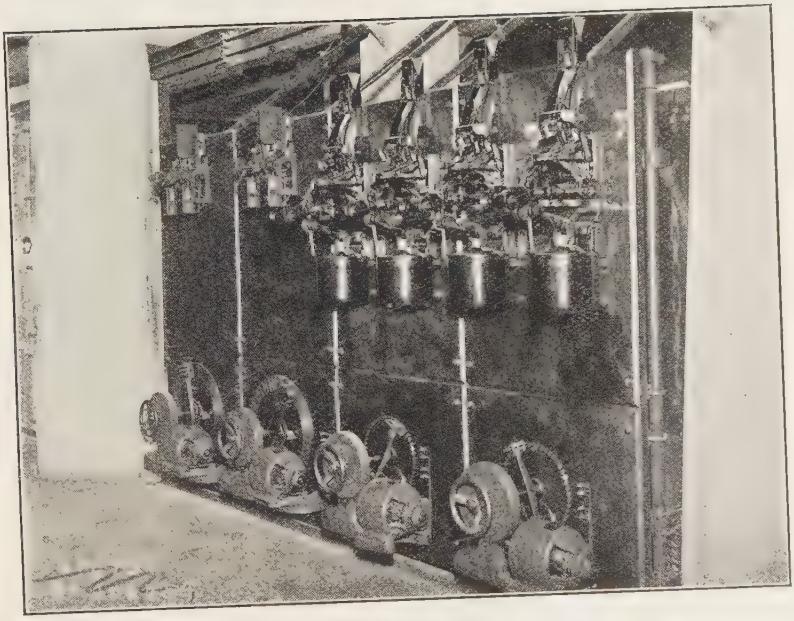


FIG. 4—EXCITER AND FIELD SWITCHBOARD, OLYMPIC POWER COMPANY

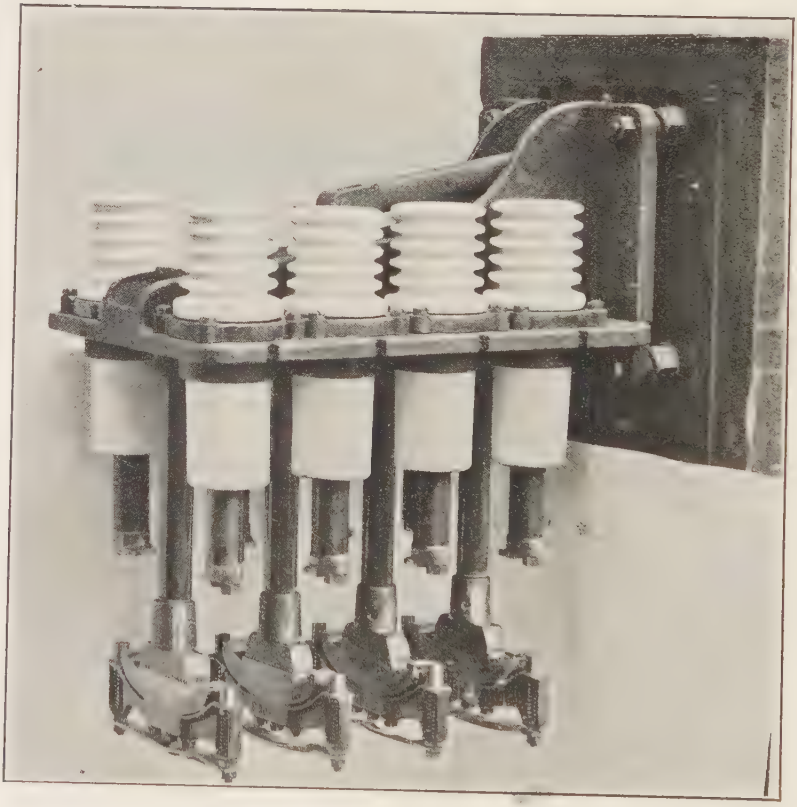


FIG. 5—300-AMP., 15,000-VOLT, 3-POLE OIL-BREAKER, COMMON FRAME

the face-plate a signal switch is provided to actuate a lamp on the desk when the arm is bridging two contacts. The face-plate is also provided with a limit switch, which opens up the motor circuit when the arm has reached the limit of its travel in either direction, and the connections are so made that, while the motor can no longer be operated in one direction, it can be run in the opposite direction.

2-C APPARATUS—OIL CIRCUIT-BREAKERS

Probably the most important portions of the switching equipment for high-tension power transmission are the oil circuit-breakers used in the generator, transformer and transmission-line circuits. Owing to the great range and the amount of current, voltage and power to be handled by oil circuit-breakers for such circuits, various types have been designed to suit different conditions, but the essential feature of any oil circuit-breaker is the opening of the electric circuit under oil, and the smothering of the arc in a comparatively restricted space. For moderate amounts of power, where the size and cost of the breaker is to be kept to a minimum, it is often possible to locate all of the poles of the breaker in one oil tank. For slightly larger amounts of power, each pole is placed in a separate oil tank, but all poles are mounted on the same frame; for still greater amounts of power, at moderate voltages, each pole is in a separate tank, and each tank is in a separate masonry compartment; while for very high voltage work, each pole is in a separate steel tank of such substantial construction as to be proof against any explosion due to the effect of short-circuit.

Figure 5 shows a 300-ampere, 15,000-volt, 3-pole, oil circuit-breaker, with all poles mounted on the same frame, each pole being in a separate welded steel tank. In this breaker the main contacts are made in the form of a laminated copper brush, while butt-contacts are used as arcing-tips to take the final break. This type of breaker is made in capacities up to 2000 amperes at 600 volts, 200 amperes at 22,000 volts, and can readily be arranged for either hand or electrical operation.

Figure 6 shows a 3-pole breaker that is built in capacities up to 3000 amperes and 600 volts, and 100 amperes at 33,000 volts. Each pole of the breaker is intended for mounting in a masonry compartment, and 2, 3 or 4-pole units are made by

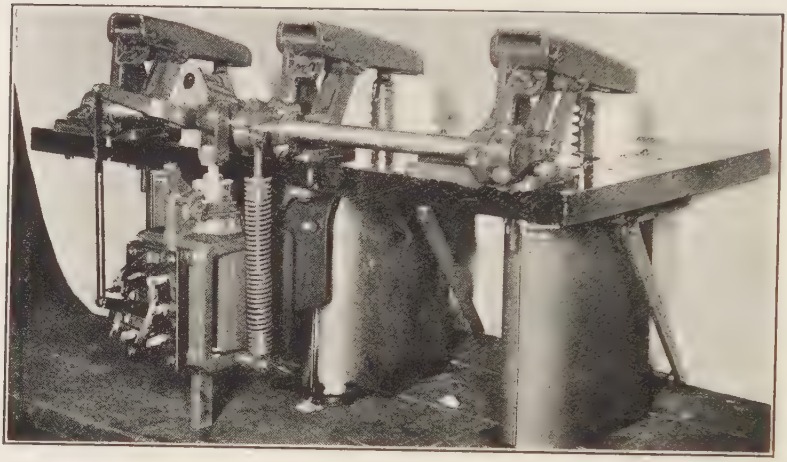


Fig. 6—3-Pole Oil-Breaker, Compartment Type, Moderate Capacity

Fig. 7—3-Pole Compartment Type Breakers, Winnipeg Municipal Plant

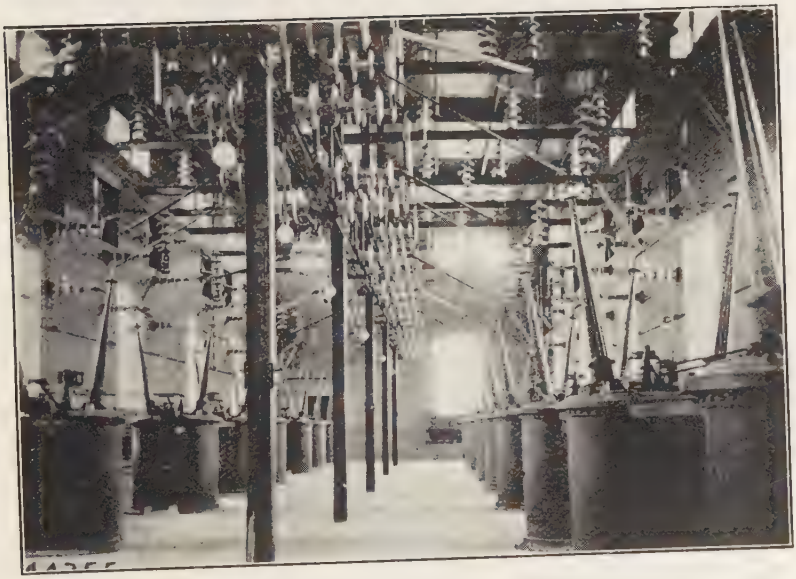


Fig. 8—110,000-Volt Oil Breakers, H. E. P. Comn. of Ontario

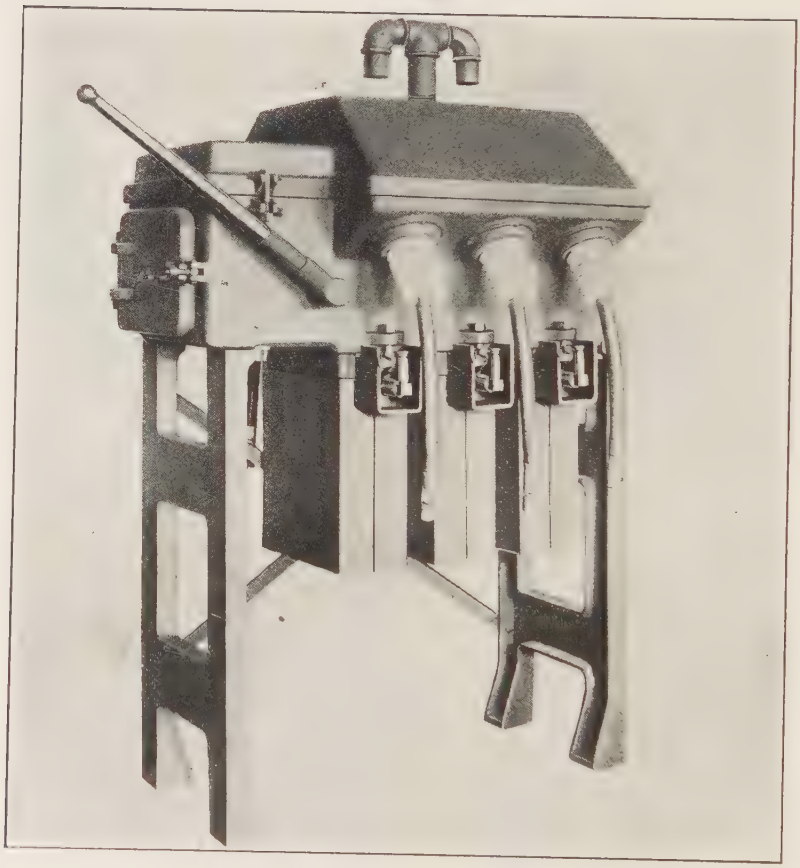


Fig. 9—Out-door Breaker, 300-Amp., 25,000-Volt

mechanically connecting together the proper number of poles and operating them by means of a powerful solenoid. As may be noted, the mechanism and the terminal insulators are mounted on a treated soapstone base, and the 2-pole, double-throw, mechanically operated switch is provided for controlling the signals on the switchboard.

Figure 7 shows a number of heavy capacity, solenoid-operated oil breakers installed in the generating station of the Winnipeg municipal plant. This type of breaker is built in capacities up to 3000 amperes and in voltages up to 33,000, and is used in stations of the largest capacities. Each pole of the breaker is inclosed in a fireproof masonry structure, and, in this particular installation, doors with clear wire-glass panes are provided for the front of the structure, to permit the inspection of the breaker and the observation of the height of the oil in the tank as shown by the gauge-glass. With this type of breaker, both terminals of each pole are placed in a single oval steel tank with welded seams and with insulated lining, each tank being provided with a gauge-glass for observing the height and condition of the oil. The leads of this breaker leave the top of the tank and pass out through porcelain bushings set in soapstone blocks in the back wall of the structure, coming out in separate compartments to keep them isolated from each other, and the leads to the bus-bars, feeders, generators, etc., may all run upward or all downward, or some of them up and some down. This flexibility is often of great advantage in permitting the placing of the generator breakers on one floor with the bus-bars above them and below the feeder-breakers, thus minimizing the amount of space required and material needed.

Figure 8 shows an installation of 110,000-volt steel tank oil circuit-breakers in the switching station of the Hydro-Electric Power Commission of Ontario, at Dundas. As may be noted, the oil circuit-breakers are provided with welded steel tanks with treated lining, and each tank, containing the two terminals of one pole, is mounted independently, the only connection between the tanks, forming a 3-pole breaker, being made by a pull-rod, so that the spacing of the poles can be made to suit the station wiring. This type of breaker is provided with condenser-type bushings solidly clamped to the cover. This construction permits the assemblage of all of the mechanism on this cover, and greatly

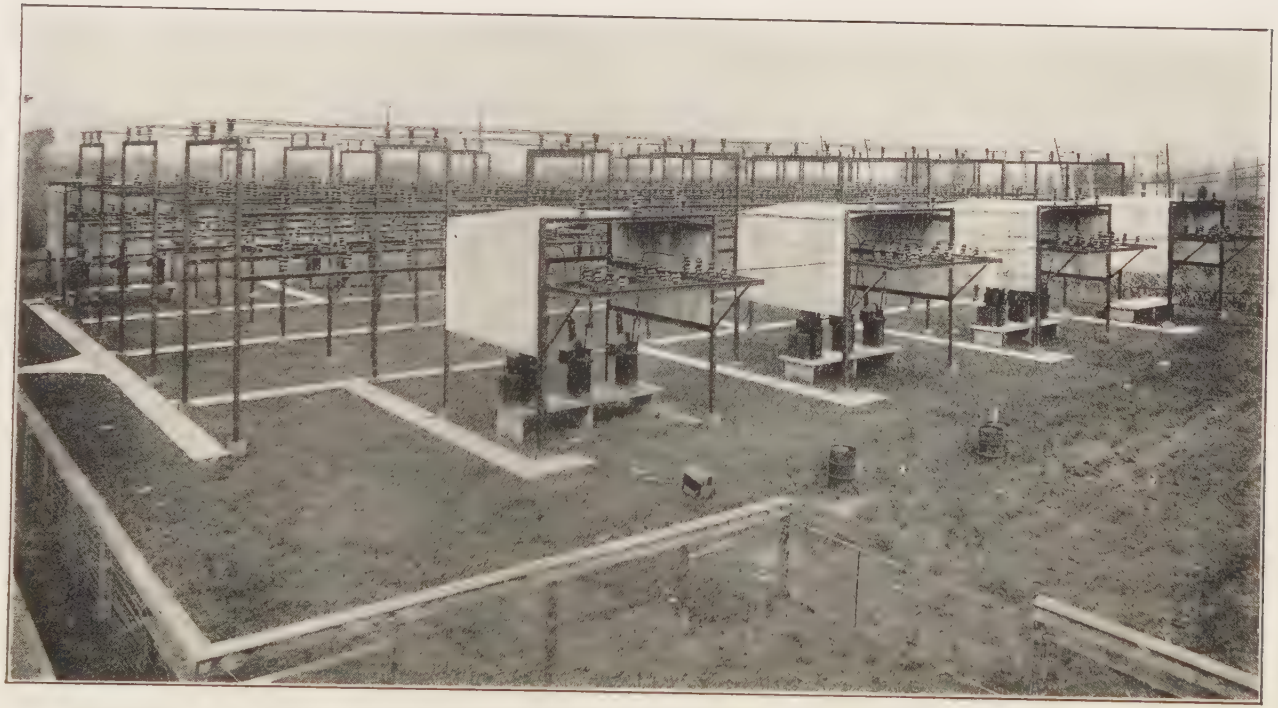


Fig. 10—Out-door 44,000-Volt Breakers, Dominion Power Company

simplifies assembling and inspection. This breaker has its stationary contacts deeply immersed in oil and screwed directly on the end of the brass tubes that form the leads through the condenser bushings. The movable contacts are self-aligning, and the contacts are provided with a heavy spring that is compressed when the breaker is closed, a wiping motion being obtained until a solid butt contact is reached. Series transformers for the operation of ammeters and relays are clamped directly around the condenser bushing-leads, which form single-turn primaries and permit the use of a simple, compact and cheap form of series transformer.

Among the latest developments of oil circuit-breakers for high-tension service is the building of breakers suitable for out-door service.

Figure 9 shows the out-door type of breaker designed for 300 amperes and built for voltages up to 25,000. As may be noted, the mechanism is completely covered by a weather-proof housing provided with an air-pipe for ventilation. Automatic operation is obtained by means of a tripping device fed from the secondaries of current transformers located under the weather-proof housing. Each pole of the breaker is in a separate oil-tank provided with an oil-gauge for observing the height and condition of the oil, the contacts and terminals of this breaker corresponding with those shown for the in-door type of breaker (Fig. 5).

For out-door service at high voltage a modification of the condenser-bushing type of breaker is used.

Figure 10 shows some of the 44,000-volt out-door type oil circuit-breakers installed near Hamilton, Ontario, in the lines of the Dominion Power and Transmission Company. As may be noted, a concrete roof has been provided over the breaker to keep it comparatively free from snow. Some similar breakers for the same voltage, entirely exposed to the weather, are in use on the lines of the Southern Power Company, in North Carolina, and some 66,000-volt breakers are in service on the lines of the Ontario Power Company. For out-door service, the condenser bushing leads of the breakers are covered with a series of porcelain insulators, and the space between the bushings and the insulators is filled with a moisture-proof compound. The operat-

FIG. 11—OUT-DOOR 100,000-VOLT BREAKERS, SOUTHERN POWER COMPANY

ing mechanism is covered by a metallic hood, and the pull-rods connecting the various poles of breakers pass through pipes. The various joints are made thoroughly water-proof, and these breakers have been operating very satisfactorily for over a year.

Figure 11 shows an installation of seven out-door circuit-breakers in the 100,000-volt circuits of the Southern Power Company, at their Salisbury switching station, in North Carolina. In this switching station the oil circuit-breakers are placed on concrete foundations under the terminal towers to which the lines are brought and which carry the disconnecting switches and the out-door local bus-bars. In installing the breakers, great care was taken, and all joints were treated with a heavy gum as a safeguard against moisture, and the breakers are painted regularly, like any other steelwork exposed to the weather. Samples of oil are taken from the bottom and top of the circuit-breaker tanks at regular intervals, and any evidence of an excessive amount of carbon in the oil means the immediate change of the oil.

2-D APPARATUS—DISCONNECTING SWITCHES

In all high-tension circuits it is customary to install knife-type disconnecting switches for isolating oil circuit-breakers, feeders, etc., and for making various connections that do not have to be opened under load. For voltages of 3300 or less, these disconnecting switches are mounted directly on a base of soapstone, marble or similar material, while for higher voltages insulators of various kinds are used to support the switch jaws. Up to 33,000 volts, these disconnecting switches are made either front connection or rear connection or both. For higher voltages they are invariably made front-connection only.

Disconnecting switches are ordinarily operated by means of a long wooden pole with a hook on the end, but for extremely high voltage service, particularly for out-door work, a different type of disconnecting switch is frequently used, consisting essentially of a number of pillar-type insulators mounted on a suitable framework and arranged so that they can be mechanically rotated by means of a suitable mechanism. With this type of switch the operating mechanism can be thoroughly grounded, and there is little danger to the station attendant.

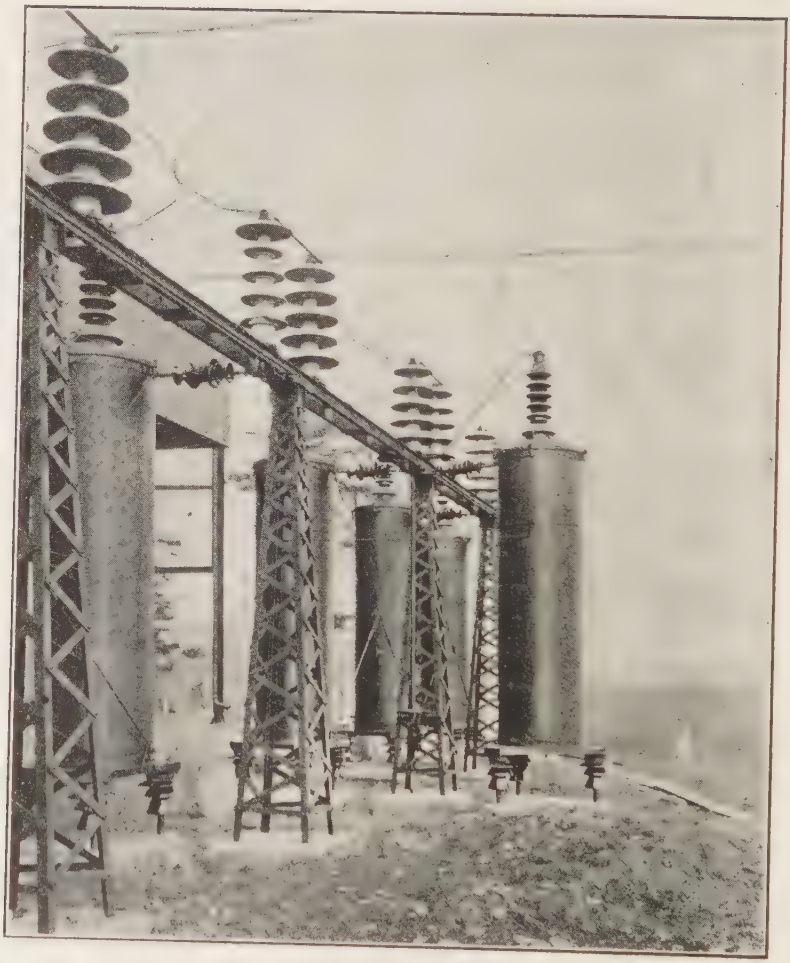


FIG. 12—110,000-VOLT ARRESTERS, H. E. P. COMN. OF ONTARIO

2-E APPARATUS—LIGHTNING ARRESTERS AND CHOKE-COILS

Without going into the theory of lightning protection, it may be stated that experience has shown the necessity of providing a safety-valve or by-pass on high-tension circuits, so that abnormal potentials may be safely dissipated without damaging the electrical apparatus.

An ideal lightning arrester should take no current at all at the ordinary operating potential, but, if there is any potential much higher than ordinary, it should pass enough current to limit the abnormal potential to some safe value. When the abnormal potential ceases, the arrester should stop taking current from the line. The closer an arrester approaches these ideal conditions the better the arrester, and many designs have been brought out for various classes of service. The one that has proved to be the most satisfactory in actual operating service is the electrolytic lightning arrester.

Figure 12 shows an out-door installation of electrolytic lightning arresters furnished for the protection of the 110,000-volt transmission lines of the Hydro-Electric Power Commission of Ontario. These lightning arresters are provided with a horn-gap device mounted on a metal framework and arranged so that the length of gap can easily be adjusted while the arrester is in service. With one position of the gap, the line-current will arc across the gap and charge the electrolytic cells for the purpose of maintaining a film of oxide on the aluminum plate. In the second position, the gaps are so set as to discharge only at a predetermined point slightly above the operating voltage, while in the third position the gap is so large as to prevent the possibility of arcing across. In this manner the horn-gap acts as a disconnecting switch when it is necessary to inspect the tanks containing the electrolytic cells.

The arrester itself consists essentially of a system of nested aluminum cup-shaped trays suitably supported and arranged in a steel tank containing a liquid electrolyte which forms insulating films on the surfaces of these trays. These films prevent the passage of current at normal voltage, but break down at abnormal voltages, forming a free path for static charges to pass to earth.

On the cessation of the abnormal stress the films regain their original resistance.

In addition to the lightning arrester itself, an important element in the proper protection of circuits against static disturbances is the installing of choke-coils, whose inductance acts as a reflector to high-frequency waves.

One type of choke-coil used to a large extent is made by winding wire or copper strap on circular or elliptical center-blocks, with heavy insulation between turns. The coils are without iron and are arranged for mounting on the station wall or a suitable framework by means of a clamping device placed on a suitable insulator supported on the bracket. Coils of this type have been built for voltages as high as 77,000, and in capacities up to 1200 amperes at 11,000 volts.

For high-voltage work, transformers having their end-turns provided with additional insulation, choke-coils of a comparatively small choking effect have been found to be sufficient, and these are usually made of the open, helical form. In one type the coil is made of aluminum rod wound into a helix of about 15 in. in diameter and about 20 turns, and the coils are arranged for support on insulators, or are placed directly in the main wiring and arranged for in-door or out-door mounting.

3-A STATION—GENERAL

For high-tension power transmission, the arrangement of the switching equipment is one of the features of design in the station of extremely vital importance, and the whole arrangement of one portion of the station ordinarily depends on the proper location of the switching equipment.

It is customary to place the transformers and their high-tension switching equipment in a separate portion of the power-house or in a separate building, and the transformers and switch-gear are grouped in a manner to secure the most satisfactory arrangement.

With bus-bars and connections where the current exceeds 600 or 800 amperes, it is usual to employ laminated copper straps, while with smaller currents, cable, wire, rod or tubing is used. The advantages of laminated copper straps are the large amount of radiating surface secured with the small amount of material and the ease with which it is possible to taper the bus-bars so

as to utilize the material to the best advantage. Another great advantage is the facility with which additional straps may be added if it is desired to increase the capacity of the bus at any time.

For extremely high voltages, with the corresponding small current that has to be carried, copper tubing for bus-bars and connections has many advantages over rods, wire or strap, these advantages being principally increased stiffness with the same amount of material, large and effective radiating surfaces, and ease of making connections by flattening the tubing out and bolting it together at points desired. Tubing of approximately 1 in. outside diameter used on extremely high voltage circuits is not apt to be troubled by the brush-discharge or corona effect that is sometimes noted with small wires or strap having sharp edges.

3-B STATION—IN-DOORS

Figure 13 shows the plan view and Figure 14 the sectional views of a plant that will ultimately contain four 6000-kva, 3-phase generators; two 240-kw, 250-volt, compound-wound exciters; four banks each of three 1750-kva, single-phase transformers stepping-up to 100,000 volts star high tension; four 100,000-volt transmision lines; three 1750-kva, 3-phase transformers stepping-up to 42,000 volts star; two 42,000-volt, 3-phase transmission line and three 75-kva, step-down transformers for local service. The original installation comprises approximately only one-half of the total final installation. The original portion is shown in full lines, while the future equipment has been dotted.

As may be noted, particularly from the sectional view, Figure 14, the portion of the building containing the switch-gear is arranged on two floors. The lower floor has the low-voltage oil circuit-breakers with their bus-bars and connections, as well as the 75-kva local service transformers, while the upper floor has the oil circuit-breakers, disconnecting switches, bus-bars and connections in the 42,000-volt and 100,000-volt circuits.

In the center of the building have been placed the three 1750-kva, 3-phase transformers used for stepping-up to 42,000 volts, while on each side of the center the banks of transformers stepping-up to 100,000 volts have been located.

For Figure 14, one section has been taken in such a manner

A
B
C
D
Control Desk
Rheostat Rack
Exciter Sw. Bd.
Temporary Partition
Future
240 K.W. Exciter and Water Wheel Turbine
Future
Ex. Pedestal
240 K.W. Exciter and Water Wheel Turbine
Trench for Gen. Leads in ground floor
3500 H.P. Water Wheel Turbine
6000 K.V.A. Gen.
3 Ph. 4000 Volt.
Trench for Gen. Leads in ground floor
3500 H.P. Water Wheel Turbine
6000 K.V.A. Gen.
3 Ph. 4000 Volt.
Future
6000 K.V.A. Gen.
Future
3500 H.P. Water Wheel Turbine
Trench for Gen. Leads in ground floor
Future
6000 K.V.A. Gen.
Future
3500 H.P. Water Wheel Turbine
Trench for Gen. Leads in ground floor
9600
9000
8000
6000
3000
Oil Rheostat on Lower Floor
100000 V. D.S.Sw.
100000 V. D.S.Sw.
100000 V. Disc.
100000 V. D.S.Sw.
Line Breakers
Transformer Breakers
2-1750 K.V.A. 4000/100000 V. Trans.
Trans. Bkrs.
Bus Sect. Dis. Sw.
Bus V. Bkrs.
75 K.W. Local Service Trans. on floor below
1-1250 K.V.A. 3 Ph. 4000/400 V. Trans.
Bus Sect. Dis. Sw.
Trans. Bkrs.
Future
Bus Structure on floor below
Future
Trans. Bkrs.
Trans. Bkrs.
Trans. Bkrs.

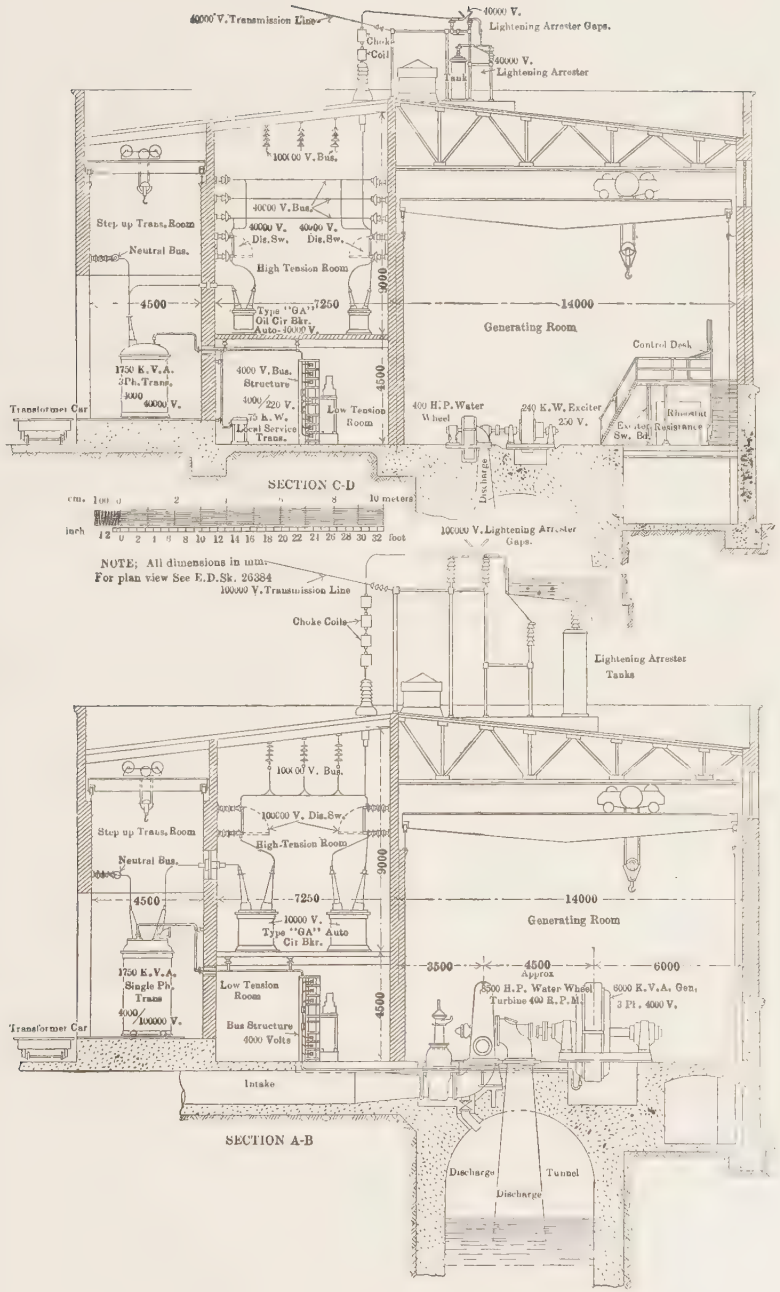
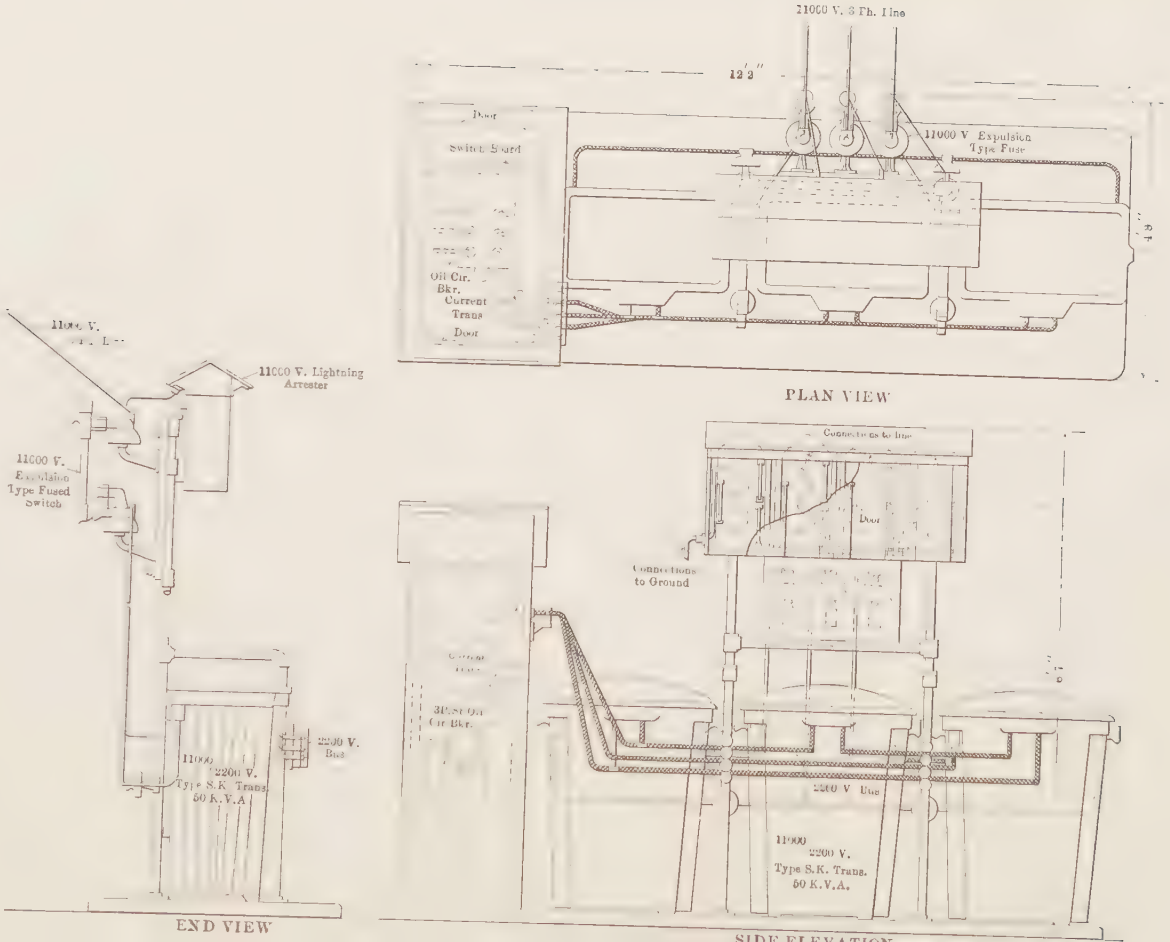


FIG. 14—SECTIONAL VIEWS 100,000-VOLT IN-DOOR STATION


11000 V. 3 Ph. Line
12' 3"
Door
Switch Board
Oil Cir. Bkr.
Current Trans
Door
11000 V Expulsion Type Fuse
PLAN VIEW
11000 V.
11000 V. Lightning Arrester
11000 V. Expulsion Type Fused Switch
2200 V. Bus
11000 2200 V. Type S.K. Trans. 50 K.V.A.
END VIEW
Connections to line
Door
Connections to Ground
2200 V Bus
11000 2200 V. Type S.K. Trans. 50 K.V.A.
SIDE ELEVATION

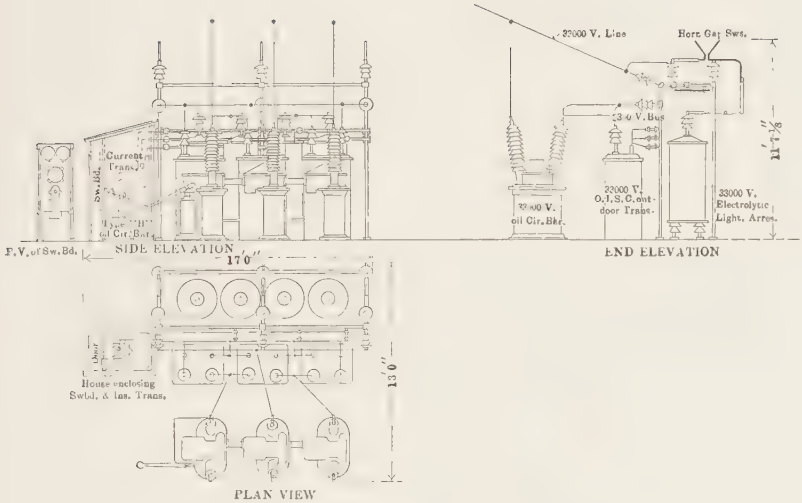


FIG. 16—33,000-VOLT OUT-DOOR STATION

as to show the arrangement of the generators and the single-phase transformers stepping-up to 100,000 volts with their switch-gear, while the second section is taken to show the arrangement of the switchboard gallery, control desk, field switchboard, exciters, local-service transformers, and the 3-phase transformers stepping-up to 42,000 volts. The building is so constructed that one crane can readily handle any of the generators or exciters. A second smaller crane runs over the transformer compartment and can be used for handling any of the large transformers. Each transformer is mounted on wheels, so that it can be readily run outside the building.

As may be noted, the 42,000-volt bus-bars are supported on pin-type insulators attached to the side walls, while the 100,000-volt bus-bars are hung from suspension insulators attached to the roof girders.

The choke-coils and the electrolytic lightning arresters for the 100,000-volt service are located outside on the roof.

3-C STATION—OUT-DOORS

Owing to the cost of providing suitable buildings for transformers and switch-gear operating at extremely high potential, and to the fact that transformers and switch-gear can be made suitable for out-door service, the question of out-door transforming stations is one that is receiving a great deal of attention from engineers.

Figure 15 shows a small transformer station for operation on an 11,000-volt circuit, the automatic protection of the transformers being secured by means of out-door type expulsion fuses.

Figure 16 shows the somewhat similar out-door arrangement for 33,000-volt service, using an oil circuit-breaker for securing the necessary automatic protection for the transformers, and utilizing an electrolytic lightning arrester for static protection.

Out-door stations are also being built for large amounts of power, and Figure 17 shows such a station for the control of 110,000-volt circuits and four banks each of three 3333-kva transformers stepping-down from 110,000 to 11,000 volts for local distribution.

As may be noted, the high-tension busses and the disconnecting switches are mounted on steel structures supported on towers of wind-mill design, while the oil circuit-breakers and trans-

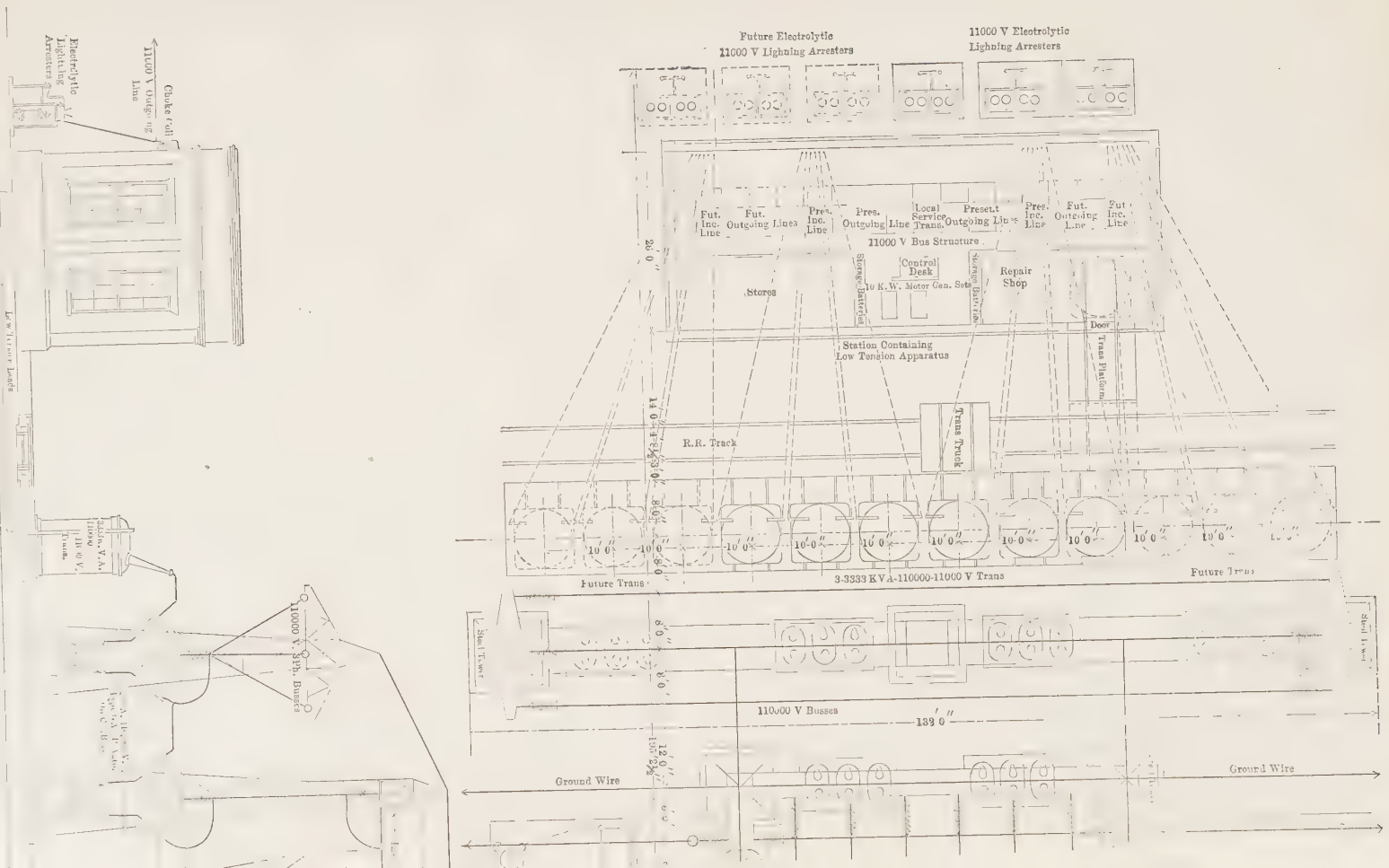
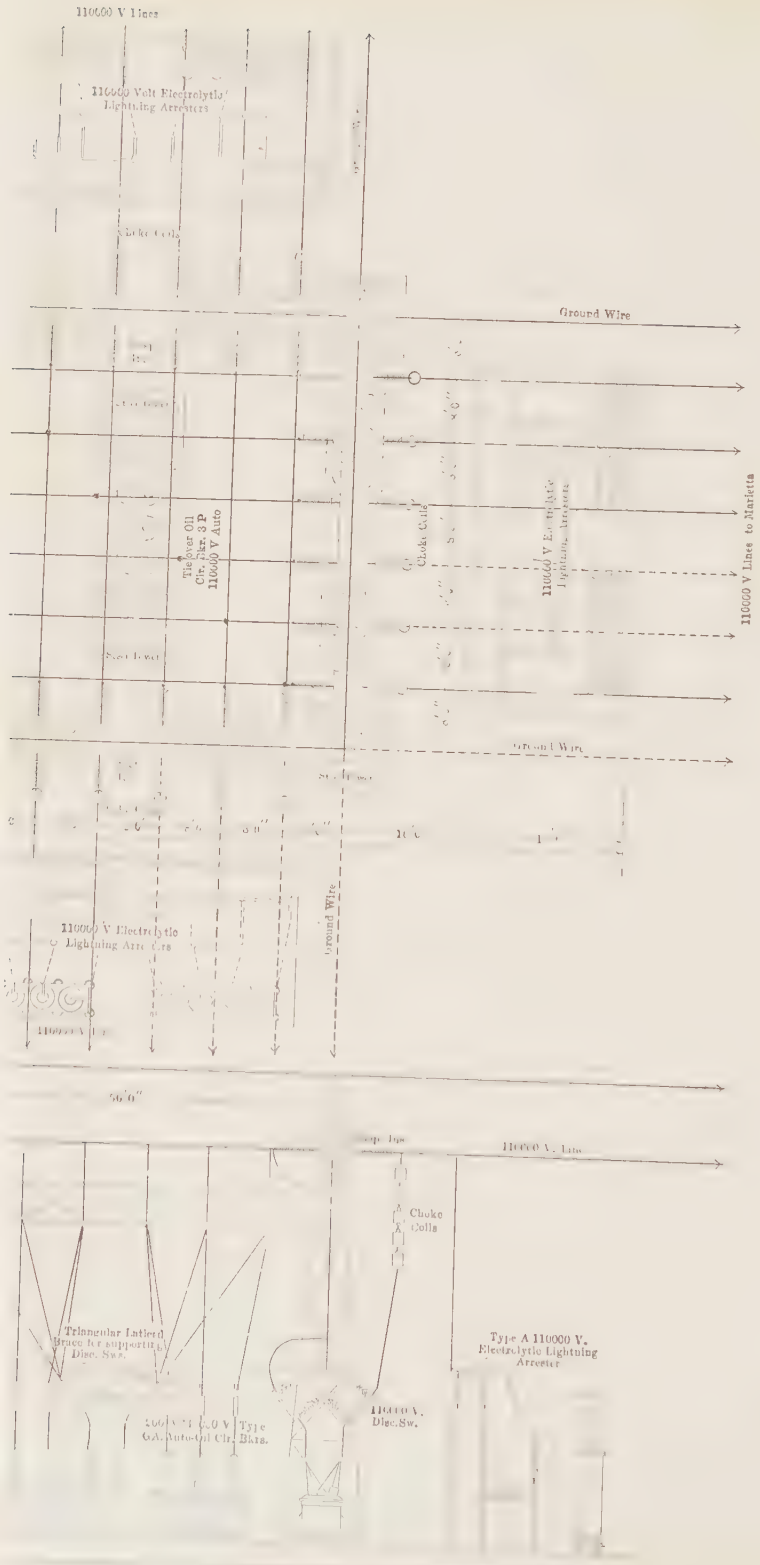


FIG. 17—110,000-VOLT OUT-DOOR


110000 V Lines
110000 Volt Electrolytic Lightning Arresters
Choke Coils
Ground Wire
Choke Coils
110000 V Lines to Marietta
Ground Wire
110000 V Electrolytic Lightning Arresters
Ground Wire
56'0"
Choke Coils
Triangular Lattice Brace for supporting Disc. Sw's.
Type A 110000 V. Electrolytic Lightning Arrester
110000 V. Disc. Sw.

TION

formers are located on the ground, the oil circuit-breakers being placed below the disconnecting switches.

Owing to the number and capacity of low-tension circuit-breakers needed for properly distributing the 11,000-volt current in a 40,000-kva installation, it was necessary to provide a small building to contain the oil circuit-breakers and bus-bars. This building also contains a repair shop, small local-service transformers, motor-generator set, storage battery, etc., as well as the switchboard on which the controlling devices for the various circuits are mounted, with their instrument relays, etc.

In this paper it has been possible to touch only on some of the most important features of switchboard practise for high-tension power transmission, and it is hoped that the discussion will bring out whatever points of importance may have been overlooked.

DISCUSSION

Mr. A. J. Bowie, San Francisco: One of the many interesting subjects brought up in Mr. Hayes' paper is that of the location of transformer stations. It is by all means advisable to cut down, wherever possible, the cost of power distribution, and in this connection the elimination of substation buildings is a matter of importance. For many years, since the potential of distribution systems was from 1000 to 2400 volts, it has been the practise to use outdoor transformers for power and light distribution. It is only within the last few years, however, that the practise has extended to installations for higher voltages. To meet the demand for outdoor stations required the development of both transformers and switching apparatus adapted to withstand climatic conditions in the open air. For this purpose two types of switches are available—the outdoor oil switch and the air-break switch. For breaking under load it is essential that the air-break switch be of the horn-type, as it is impracticable otherwise to secure a break sufficiently long to handle the high voltages and required power.

Both air and oil switches have been constructed to handle the highest voltage at present demanded. In either transformers or oil switches for outdoor use it is essential to provide thorough protection against the possible entrance of either moisture or

dirt. For such apparatus the entrance bushing must be much larger and more expensive than would be required for indoor use. This is a matter of some importance, when the pressure is very high, say over 100,000 volts.

With outdoor stations, in case it should be necessary to examine a transformer, unless the weather were exceptionally good, it would have to be taken under cover. Such examination would, however, be of infrequent occurrence. In the case of an oil switch, however, it may frequently be necessary to examine the switch, and to renew the contacts in case they have burned. In this event, particularly in the case of a switch for very high pressure, it is undesirable to have to disconnect the switch and remove it under cover before an examination can be made, not alone for the labor involved, which is considerable, but also on account of the time that the switch must be out of service. These are serious objections, particularly since the oil switch cannot be inspected when alive, and ready facility of inspection is by all means advisable. For this reason many engineers would not consider the installation of outdoor oil switches for very high pressure, and feel that these switches should by all means be located indoors, as a very small percentage of moisture would be fatal to the operation of the switch.

The housing of switches in many cases may equal in cost the initial cost of the switch, thus doubling the expenditure for installation. The horn-type air switch, on the contrary, is especially adapted for outdoor use, as it allows immediate inspection when alive, and requires no expensive bushing. In addition to the entire saving of the housing, it is cheaper than the oil switch, thus making a considerably more economical installation.

Switching apparatus in a plant must operate under the most severe requirements. Hence it is on the side of safety to place a switch wherever, in event of accident, the damage will be minimized. It is certainly far safer to locate switches out-of-doors than indoors, not alone for the reasons mentioned above, but also as it provides complete protection for all wires entering the building.

With switches and transformers out-of-doors, the arrangement should be such that the worst accident which can well happen to one piece of apparatus, will not damage any other apparatus. For this reason ample spacing must be allowed.

I would like to ask Mr. Hayes if any protection is made against excessive absorption of heat from the sun by the transformers located in the open? Are the cases painted a light color, or is water cooling relied on to handle the additional heat received from the sun?

The open-air substation represents a material saving in cost, and that saving will prove a potent factor in the development of power transmission.

Mr. D. F. McGee, Portland, Ore.: I would like to know from Mr. Hayes whether they have any installation of outdoor transformers and lightning arresters in this section of the country; that is, where they are exposed to considerable moisture, cold and snow, and if so how long have they been in operation. We are particularly interested in that, inasmuch as we are operating over a very large territory, serving an irrigation district where the cost of transmission lines, distributing lines and transformer stations is high compared with the income which we are deriving from them at present, and for that reason we are interested in securing an installation which will be as cheap as possible. We have ordered some outdoor type transformers. They are not yet in service, however, but we expect to have them before long. For that reason I would like to get the benefit of some other engineer's experience in handling such installations.

Mr. Rushmore: Pardon me for breaking in once more, but this is a subject in which I have been so very actively engaged of late that I want to say a few words on the general subject of high voltage, and especially in connection with switchboard and transformer usage.

There are now in operation a considerable number of outdoor substations, and some of them have been subjected to the very worst weather conditions. A photograph was recently taken of one in the Carolinas, showing the sleet and ice extending for several feet below the conductors and over the insulators, which is about the worst thing imaginable, yet interfering in no way with the continuous operation of the system. The continual increase in the voltage used for transformers, switches and line insulators, has put a great deal of pressure upon the manufacturers of this class of apparatus, and a very large amount of experimental work has been done and is being done in order to

develop apparatus which will be entirely satisfactory under commercial conditions; for, as has been said, the object of power transmission work and the reason for designing and using an out-of-door substation or any other form of substation, is to make the lowest possible investment charge, on which interest is to be earned. This, in a number of cases, has forced the use of out-of-door substations and of out-of-door switches and transformer buses, and so forth; and those of the highest pressure have necessarily not been in operation over a very considerable time. But so far those with which I have been familiar have given entirely satisfactory operation.

As you may possibly know, a scheme is on foot at present on the Pacific Coast for the use of extremely high voltages, even under the present conditions. There are still a large number of disturbances on 100,000-volt systems and apparently the factor of safety on such systems must be very much increased. Factors which can be ignored at lower voltages become of increased importance as we push the voltage up, and those of you who have had experience on such systems know very well that it is foolish to go far into the future until the present voltages have been made absolutely satisfactory.

Now, it is possible, apparently, to insulate the line for any voltage which we want to use, and this throws all the strain on the apparatus, and it is a question whether or not some weak point in the system will not have to exist. It is a question whether any apparatus can be built which will stand the strain brought on a line or a system by severe lightning disturbances, about which you in this part of the country know only a part. Lightning disturbances are said to follow a cycle of about 11 years of sun-spot activity, and apparently this year they are extremely bad. It is possible that a voltage is set up on such a system which would break down any apparatus built with a commercial factor of safety; and some weak spots must exist. Up to the present it has been the transmission lines, and no transmission line with which I am familiar at 100,000 volts, with the possible exception of the Ontario Hydro-Electric, but what has "slopped over," as it is called, that is, discharged over the insulators at times of extreme disturbance.

By insulating a transmission line as is now being considered, possibly beyond the voltage of the lightning disturbance, the

strain on the apparatus becomes terrific. That is the only word to use when you see the actual physical forces displayed around the insulators and apparatus under these extreme conditions.

The bushings which in low voltage were relatively unimportant have become of the highest importance, and have been developed with the greatest of care. Satisfactory bushings for these voltages have been developed and are in operation, even at very much higher voltages than I mentioned. But the actual work and operation under these extremely high voltages, as many of you know perfectly well, is a very different thing in practise from what it is in discussion, and while wishing to thank Mr. Hayes for having brought up the subject and covered it in his usual comprehensive manner, we have felt it rather desirable at this time to bring out a point regarding the difficulties which will have to be met at a very great increase in voltage, rather than to let it be supposed that we are going to extend indefinitely in the future, and are at present in shape to consider that this would be satisfactory under ordinary operating conditions.

Mr. L. N. Peart, Fresno, Cal.: I would like just to answer a question. Mr. Bowie asked Mr. Hayes about this outdoor type of transformer, if anything was done toward painting the case or protecting it from the sun. We have had for one year several outdoor stations of about 600-kilowatt capacity, and we are taking very careful readings. This is in the San Joaquin Valley, where the temperature gets very high; as the saying goes, we have 107 degrees in the shade, and no shade, so we have to watch the peak conditions. Furthermore, the transformers are situated sometimes where it is very hard to get cooling water, and they are self-cooled. For that reason we have to watch the transformer temperature very carefully in the hot weather, and we had always put up shields to protect them from the direct rays of the sun, until, on making tests, we found that those shields prevented the radiation of the heat. On actual tests the transformers without the shield were cooler than those with it, and the only thing we do now to dissipate heat is to paint the shells white. The transformers have carried so far 80 or 90 per cent full load in the hottest time of the year.

Mr. Hayes: I think Mr. Peart has answered Mr. Bowie pretty fully about painting casings and putting up shades. With water-cooled transformers it is not usually found necessary to

protect in any way; by slightly increasing the quantity of water the extra heat can be readily taken care of.

Answering Mr. McGee's question about outdoor installations exposed to cold and snow, there are, as mentioned in the paper, outdoor oil circuit-breakers in the lines of the Ontario Power Company, up near Buffalo, and in the Dominion Power and Transmission Company, near Hamilton, and the temperature there gets pretty cold. As Mr. Rushmore mentioned in connection with sleet on the switches. I also have seen a photograph taken, corresponding with Figure 11 in the paper, of the switches at the Salisbury Station of the Southern Power Company, where the sleet entirely covered the porcelain over the bushings, and the service went on just as though there were no cause for trouble.

I believe I have answered the main questions brought out.

(Adjourned.)

THIRD POWER TRANSMISSION SESSION

Thursday Afternoon, June 13

The Chairman, Mr. H. L. Doherty: The first order of business is the report of the Committee on Receiving Apparatus for Use on Transmission Lines. Mr. F. B. H. Paine, the Chairman of that committee, is not here and the report will be presented by Mr. W. N. Ryerson, of Duluth, Minn.

REPORT OF COMMITTEE ON RECEIVING APPARATUS FOR USE ON TRANSMISSION LINES

Companies engaged in the transmission of electric power have made great strides in the improvement of their service, and for some time past it has been felt that the users of the transmitted energy, whether the ultimate customer or the local distributing organization, have not used and are not using controlling and operating apparatus of such design and in such manner as to get the best results from energy supplied by high-voltage transmission lines having miscellaneous customers with fluctuating loads.

Your committee was appointed in February of this year, for the purpose of inaugurating a study of this problem, and to enable its report to be available for the Convention it was further required that it report almost immediately. It is hoped that the facts presented will excite general interest and induce other companies using or supplying transmitted power to adopt the recommended methods of study, records and investigations to be placed at the disposal of succeeding committees in order that subsequent reports may cover the field broadly and with increasing benefit to all.

An analysis of the disturbances affecting continuous delivery of power during 1911 as found on one 500-mile, 100,000 horsepower, 60,000-volt system, "Y" connected with 700-ohms neutral resistance, are grouped in table A under three classes, and the results of three widely differing customers are fairly representative:

TABLE A

Cause	Customer A Per Cent	Customer B Per Cent	Customer C Per Cent	Average Per Cent
1. Disturbances due to flashing over of insulators and similar disturbances presumably controllable as to their duration	81	82	76	80
2. Miscellaneous interruptions due to trouble on customers lines, errors in switching, etc.	12	13	19	14
3. Line failures necessitating repairs	7	5	5	6

In the first class of disturbances are included voltage fluctuations, not really interruptions but sufficient to interefere with the continuity of service of synchronous apparatus, and it is felt that this class of disturbance will be found extremely large in every high-voltage transmission system of considerable mileage, operating at 40,000 volts or more, certainly so when pin insulators are used.

While every effort should be given to improvement in the rapidity of starting apparatus in order to better results in the other two classes of trouble, it is particularly to the first class that your committee this year calls your attention, for the reason that it is its belief that service outages resulting from this class of line troubles can be immensely reduced and the greatest immediate benefit can be secured.

It is believed that voltage disturbances causing outages to customers on high-voltage transmission lines are usually of such a nature that their duration can be limited to a definite short period of time, and to such effect that with receiving equipment properly designed, controlled and operated, practically no outages will occur from this class of line trouble.

What is the character of these momentary disturbances? When one insulator flashes over, it is referred to as single-phase disturbance. The simultaneous flash over of two insulators on different phases or a temporary short between two wires of different phase is referred to as a 2-phase short. When three insulators, one on each of three phases, coincidently flash over, or a temporary short between 3-phase wires occurs, it is referred to as a 3-phase short. The insulators may be miles and miles apart. The cause of the flashing over of an insulator is ordinarily atmospheric lightning or internal static. Temporary 2 or 3-phase shorts are caused by wires swinging together or shorted by flying objects. If there be power enough in the generators to maintain the resulting arc it will persist indefinitely until the circuit is opened. As a rule it is maintained for a few seconds.

There are many causes for an arc on high-voltage systems, such as birds, kite strings, a bit of straw, etc., they being sufficient to start an arc which is afterward maintained where there is considerable power for a longer or shorter time, according to the setting of the time limit relay operating the circuit switch. The effect of any short is, however, to bring the voltage of the

system in every instance practically to zero. One often hears the expression that "the voltage drops 20 or 30 per cent." This is not the fact, as disclosed by the oscillograph. The voltage always drops not quite but approximately to zero at the arc and beyond, but between the arc and the point of generation the line loss determines the difference between zero and something more than zero potential. The reason for the erroneous idea that it drops only 20 to 30 per cent, and not to zero, is the time element or slowness of the voltmeter, together with the error of observation.

Experience shows that on the system under discussion with its neutral resistance a single-phase ground, as defined herein, has no disturbing influence on the connected apparatus. Two and three-phase short-circuits, as defined herein, have most serious effect on the connected load.

A careful record of every disturbance should be kept, including the number of phases affected, the exact hour of its occurrence, as much detail about it as possible, and a consecutive number should be given it.

Customers operating under similar conditions have a widely varying number of outages for which "interruption" is claimed. Of two large customers supplied in the same city, one has had twice the outages of the other.

Certain pieces of apparatus in a customer's plant habitually drop out of step, while other apparatus used for the same purpose stays in step for a much longer, although still for a short time. Therefore, a classification of the types of design of synchronous apparatus employed should be made; and the effect of the setting and controlling relays, both in point of time setting and current setting, should be studied. This latter may be accomplished with an oscillograph, but better by a continuously operating cycle indicator.

It must be appreciated that generalizations will not exactly correspond with observations of individual cases, but unquestionably the following conclusions are of general application, and if the suggestions are followed better service will be rendered by any system.

The best service will be secured by receiving apparatus designed and operated along the following lines:

First—The most important thing is not to cut out equipment

until it has to be cut out, or until the disturbance is shown to be more than temporary and momentary. No inverse time-limit relays should be permitted. Automatics protecting individual pieces of apparatus are as a rule set to operate in too short a period, and they should always be set for a time limit in excess of the number of cycles to which such disturbances are limited.

Second—Induction instead of synchronous motors may be used where maximum continuity of service is the first essential. Their speed regulation is practically synchronous, their efficiency practically the same, and if designed with a flat torque curve in the vicinity of normal speed, excessive power demands are avoided and a torque permitted under recovery of speed only slightly in excess of maximum load current, and this permits recovery of speed with sufficient rapidity and without manual attention on the return of current supply. The objection to induction motors, however, is their low power-factor, as it affects line regulation.

Third—Improvement in continuity of service may result where synchronous apparatus is used, if there be separate excitation of synchronous motors or rotaries, as by a belted exciter, storage battery or otherwise. That is, the exciter voltage should not be affected by variations in the electromotive force of the transmission circuit; speed variations in the apparatus are of relatively little consequence.

Technicians differ in regard to this statement, and general experimentation is needed.

It is found that in much of the synchronous equipment, rotaries or motors, instantaneous current-demand with the return of voltage is several times the normal, but as this lasts for only ten to twelve cycles it is of so short duration as to cause no overheating of the apparatus.

Fourth—Where continuity of service is the first essential, no question exists as to the benefit derived from the use of heavy copper dampers on the pole faces of rotary converters and synchronous motors.

Fifth—No experiments have been made in the use of increased fly-wheel effect nor is its necessity indicated.

Beyond the above generalization your committee does not feel justified in going at the present time. It, however, suggests that a similar committee be organized immediately, if possible

during the Convention, for the purpose of arranging further studies on transmission systems of considerable size having different operating conditions as to voltage, frequency, geographical location, class of service, etc. Nearly every company is provided with the instruments necessary for observation except two: (1) A complete oscillograph. (2) A means of determining the actual duration of every disturbance.

We urge that every effort be made either to devise or to encourage the construction of a continuously operating oscillograph.

A form for recording disturbances and a diagram of customer's apparatus, etc., are attached, which this committee believes it advisable to adhere to for the year 1912, and thereafter, probably improved upon by experience. It is felt that for the good of the cause all should use the same forms for reporting so that what is reported may be compared and tabulated.

Committee { F. B. H. Paine, *Chairman*
M. R. Bump
C. I. Burkholder
R. M. Wilson
N. T. Wilcox

NATIONAL ELECTRIC LIGHT ASSOCIATION - POWER TRANSMISSION SECTION

COMMITTEE ON RECEIVING APPARATUS

Number of Disturbance	Date and time	Load Before	Load After	Per Cent Load Loss	One, Two or three phase disturbance	Duration of disturbance in cycles	Power House Capacity	Remarks

POWER TRANSMISSION SECTION. N.E.L.A.

COMMITTEE ON RECEIVING APPARATUS

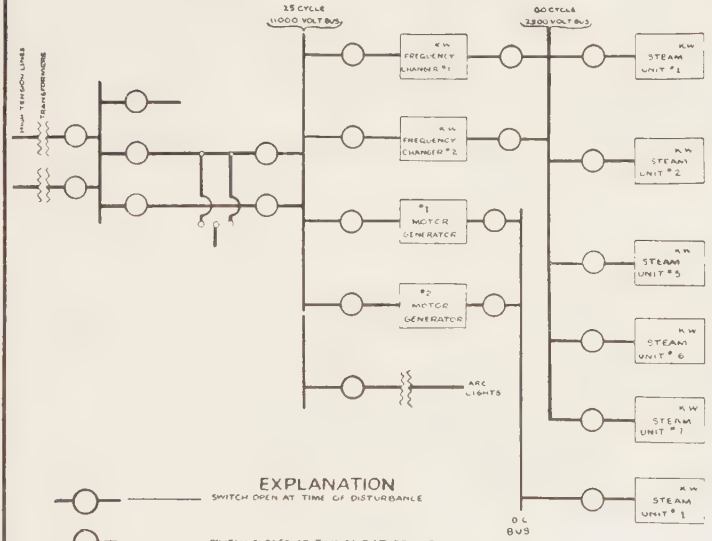
CUSTOMER'S DISTURBANCE REPORT BLANK.

DIAGRAM OF CONNECTIONS OF _____

DATE _____ , _____ A.M. _____ P.M.

TOTAL LOAD BEFORE DISTURBANCE _____ K.W. TOTAL LOAD AFTER _____ K.W.
LOAD LOST BY DISTURBANCE _____ %

THE SWITCHES INDICATED AND NUMBERED ON DIAGRAM TO BE FILLED IN AFTER EACH VOLTAGE DISTURBANCE ON THE HIGH TENSION LINE.



EXPLANATION

SWITCH OPEN AT TIME OF DISTURBANCE

SWITCH CLOSED AT TIME OF DISTURBANCE

SWITCH OPENED AUTOMATICALLY BY DISTURBANCE

SWITCH OPENED BY OPERATOR AT TIME OF DISTURBANCE

REMARKS- _____

MR. RYERSON (continuing): I would like to move, Mr. Chairman, that this or a similar committee be appointed for this coming year. I think the work that they have done is of very great importance and can be of much greater importance.

MR. D. B. RUSHMORE, Schenectady: I second the motion.

THE CHAIRMAN: Before I put the motion I will state that this committee has done a great deal more work than is reflected in this report. There were reasons why they could not bring it out at this Convention, but they are preparing, if this committee be continued, to do or to assist the committee in doing some very comprehensive and valuable work during the coming year. I think I may say without betraying the confidence of the committee, that some very important facts along this line will be brought out at our next Convention.

The motion was put to vote and unanimously carried.

DISCUSSION

MR. RUSHMORE: Mr. Chairman, just to open up the discussion in a way that will bring out the different points to be considered: In apparatus for receiving power we have power systems where the power comes in at 25 and at 60 cycles. These power systems almost always tie into large distribution systems on the receiving end. These distribution systems have, as a rule, grown up from smaller ones. They contain an Edison 3-wire system, with possibly a 500-volt continuous-current system, a 60-cycle distribution, and very often a 25-cycle system tied in together. So, whether the power comes from a 25- or 60-cycle transmission system it has to be transformed into different frequencies and voltages. The question is how to receive that power. Are we going to receive it in one main transformer station outside the city and distribute it from there; say, receive it at 60,000 or 100,000 volts and step it down to 13,000 or 2300 volts for the city? The voltage limitation that has been adopted in different towns and cities is a very important question. When we come to regeneration are we going to use induction or synchronous motor-generators, or rotary converters? Then we have the very important and necessary financial question. Practically anything can be accom-

plished by the expenditure of money, but power systems and distribution systems are put in to earn money and a limit is necessarily placed on the interest charge. How much shall be spent for safety appliances and protection, how much for duplicate bus-bars and duplicate feeder systems, and for protective apparatus? There is a very interesting limit reached in the use of lightning arresters on high-tension lines. If you want to take out a very small amount of power from a high-voltage line the cost of the lightning arrester will often exceed the cost of all the other apparatus. So there is naturally a commercial limit to the use of all safety and protective devices. How much are we justified in spending for protective apparatus?

Power received over a transmission line naturally has to compete with power generated locally for the system of distribution, and the question arises how many interruptions will customers submit to, and what sort of interruptions. Following this again is the question how much expense is warranted in preventing interruptions.

These are just a few of the problems which arise in considering a system or in determining the apparatus to be used for receiving power from transmission lines, questions which are becoming important with practically every distributing company which is getting power from any outside source, and my intention is just to bring these points up for discussion.

Mr. D. F. McGee, Portland, Ore.: The paper and the discussion bring back to me the difficulties with which we have had to contend. We are operating at 66,000 volts over a very extensive system, probably 400 or 500 miles, and are serving, among other points, an irrigation district. Throughout that district we have numerous small towns which must be supplied with power from our system. We cannot afford to keep operators at these substations, and in most cases they are equipped with self-cooling transformers. When it comes to supplying the protective devices, it is a question when we should stop. Where we are only taking off a small amount of power—we have some 250- and 300-kilowatt substations—it is out of the question to install the latest type of lightning arrester, for the simple reason that we cannot have attendants there to charge the arrester every day.

We also have to meet the question of switching. For reasons of economy it is impractical to install the latest type of

oil switches. The switch alone would cost considerably more probably than the rest of the station, as those substations are often simply galvanized-iron structures set out in the sage-brush. To meet this difficulty we have adopted a fuse type of switch, the fuse protected by a glass tube; probably the fuse and tube together are three feet long.

Now this problem comes up with the installation of either three single-phase transformers or one 3-phase transformer. For any one of various reasons there is a blown fuse on one side with the other connections and transformers in service, and we all know about what occurs. We have had several blow-outs due to the overload on the secondaries which are in service when one primary line goes out. What I would like to know from some of the members or engineers present is how they meet it. What can we do to protect those lines and to protect our apparatus on such occasions without the use of an expensive oil switch?

Mr. J. A. Lighthipe, Los Angeles: I would like to ask if you have had any experience with the apparent ageing of insulators, especially of the old pin type. The Southern California Edison Company probably installed the last high-potential system to use the old pin-type insulator—the 18-inch insulator. For the first year we had very little insulator trouble, they tested out when they were new; they tested out well at the end of the year; at the end of the second year we began to pick out bad ones. There were almost invisible cracks that would not show under casual inspection, but were found by a sharp blow on the arm. If the insulator does not ring out like a plate, then it is ready to go. It may crack in the hot summer, but under the first fog it comes open. It has now become necessary to thoroughly inspect every insulator on the lines every six months by striking with a hard stick as you would test a plate in a crockery store. We are replacing something like 100 every couple of months. It is a question of a very short time when there will be a total depreciation of these. They will all be gone in five years. The only remedy we can find now is to slowly change the towers over and install the suspension type of insulator. We started off with one type or make and we now have three different types. We had an idea at one time that an excessive amount or a poor quality of cement caused the trouble, but all three types are following the same course.

Mr. Arthur Williams, New York City: I would like to ask as a matter of information two questions. Just what is the cause of this breaking down of the insulators, to which reference has been made? Is it mechanical or electrical? And I have been very anxiously hoping to hear something about any experiments that may have been undertaken in the recent past as to the use of electric power for the aid of agriculture, not in the turning of motors, but to stimulate agricultural growth. It may be that the second item of desired information is entirely foreign to the purpose of this meeting, but nevertheless if anything has been done, experimentally or commercially, along these lines, I believe it would be of great interest to the industry.

The Chairman: The second subject we shall take up after we finish the present discussion. I myself would like to hear that discussion, because a great deal of work has been done abroad. I will ask Mr. Davidson to call for it later under Topical Discussions.

I want to ask one question: Are all of those ageing insulators porcelain?

Mr. Lighthipe: Yes, sir; 75,000-volt, 18-inch top.

I might say, Mr. Chairman, I have studied this question two or three years. We have had all the insulator makers at work on it, and know every new theory that has been advanced. A careful tabulation of points of breakage showed that they simply split in all parts, sometimes by the peak pinnacle underneath, sometimes the disc, sometimes the top, sometimes the rim. Our cure is to rebuild the line with suspension insulators, and we have had to do this while the line was alive, that is, half of the towers alive—75,000 volts.

I would like to bring up the question of reverse current relays also. Have they been worked out at all satisfactorily? Mr. Varnoy, of San Francisco, states that they are in use on his lines, but we have been afraid of them. I have invented about fourteen, but Dr. Steinmetz said they must work with zero voltage and I have stopped.

Mr. P. T. Hanscom, San Francisco: I have nothing particular to add on the reverse current relay subject. The only experience we have had with the trouble mentioned by Mr. Lighthipe occurred in the last 12 months on the lines of the Great

Western Power Company. I think in that period there have been about 12 failures of dead-end insulators. They are of the suspension-insulator type, installed in dead-end condition with jumpers around the cross-arm. The experience has been either under normal conditions or when the line was subjected to unusual stress by surges, when these strands of insulators in that position have broken down. Only once or twice out of the 12 times has it caused any serious interruption. As a general thing on the string of insulators one of the units explodes and the wire falls, but the jumper supports the wire in the clear so that the interruption is momentary; and in several cases we have found that condition after an apparent short on the line, but service continuing, the defective insulators being discovered by the patrolmen in the regular inspection of the line.

It seems very difficult to reach a conclusion as to the real cause of these failures. Apparently the combination of mechanical stress in the insulator with the electrical stress has something to do with it, for the reason that a large number of insulators of the same type installed in suspension position where the stress is very much less, from 2500 or 3000 pounds in the strain position, to 500 pounds or less in the suspension position, have given good service. These particular strain insulators were constructed of four units in series. In each case we have replaced them with single-part insulators, five units in series, and in no case have we had trouble. Other strain insulators of a heavier type, single-series unit, are installed on the line and have been there since the original construction. In no case have these heavier insulators broken down.

After considerable observation of transmission-line service I am inclined to think that we should be more liberal in the number of units used for a given voltage. In looking over the reports of different plants I find that companies which have originally installed a large number of units have perhaps been most free from troubles of any character, especially insulator troubles.

Mr. G. H. Bragg, San Francisco: In reference to the ageing of insulators, I have noticed that where the insulator has a white glaze after several years of service the glaze will be cracked in a manner similar to what you see in very old china, but in brown porcelain or brown discs we have never seen a similar

crack and we have insulators which have been in operation for seven or eight years at least.

MR. MCGEE: I would like to ask this gentleman whether he is running a grounding or non-grounding system?

MR. LIGHTHIPE: Ground wire? We ground the ends of the line.

MR. MCGEE: You use a ground wire?

MR. LIGHTHIPE: Wire ground; yes.

MR. MCGEE: There is no chance for a new circuit?

MR. LIGHTHIPE: No.

THE CHAIRMAN: I will call on Mr. Ryerson to answer the questions and close the discussion.

MR. RYERSON: I preface my remarks by saying I have not been in the confidence of the committee and the question that was brought up in regard to the non-use of inverse time alternating relays was one I had intended to ask them myself. I see no reason whatever why they should not be used under proper conditions. I have not had any direct experience with the ageing of porcelain, but I do know of a number of cases where insulators burst after installation, due, apparently, to strains set up during the cooling of the porcelain after glazing. I merely mention that as a possible cause of the trouble, although it may not explain it.

A question was asked regarding the protection of small substations on distributing lines. That is a problem that I think we have all had to work out for ourselves. The cheapest method, of course, is the use of fuses. The difficulty there is that one fuse may blow and your customer may be running single-phase and overheating his motors and other apparatus for a considerable time before it is discovered. If we could get an inexpensive circuit-breaker we would all be very happy, but I am afraid that is a long way off.

In regard to Mr. Williams' question about the use of electricity in agriculture. I have simply heard of it in a general way and I do not know of any specific cases where it has been tried.

MR. J. P. BOWDEN, Portland, Ore.: Quite frequently, although reaching out for new business, we are not justified or warranted in making an expenditure of a large amount of money for substations, and in these cases outdoor transformers are used

and these outdoor fuse switches. I would like to ask what experience other companies have had with installations of this kind, more especially as regards changes in the weather, etc., whether the transformer during the summer-time becomes too hot or if there is trouble along that line.

Mr. L. N. Peart, Fresno, Cal.: We have a few small stations in the San Joaquin Valley where the transformers are out of doors and the temperature ranges in the summer as high as 115 degrees or 120 degrees out in the sun, yet the transformers operate all right. The oil reaches a temperature of 70 degrees centigrade. In winter we are not bothered much with rain and snow. In fact, there is no snow at all; it is an ideal climate for outdoor installation.

The Chairman: The next number on the program is the paper, "Corona on High-Tension Lines," by G. Faccioli, of Pittsfield, Mass. Mr. Faccioli is unable to be with us on account of illness. Mr. E. F. Gehrkens will read the paper.

CORONA IN HIGH-TENSION LINES

The complex phenomenon known as "corona" has received in recent years the constant attention of physicists and engineers. The industry has grown so rapidly in the direction of high voltages that some anxiety is felt as to the danger of corona checking or retarding this progress. Hence an energetic effort has been made in the laboratory and in the field to understand thoroughly, and possibly to control, this objectionable phenomenon. The result of all this activity is that corona is no longer considered a limiting feature in high-tension work, at least for the present.

In the operation of high-tension systems, however, corona introduces some problems which may be summarized as follows:

First—Why is corona considered dangerous?

Second—Where is corona to be expected?

Third—How can corona be prevented?

Regarding the first question we may say in general, the presence of corona at a certain point of the system shows that a critical electric stress has been exceeded at that point. Naturally, where such critical value is surpassed, a weak point of the system is developed. While at normal operating voltage no danger may result from the presence of corona, yet when an over-tension occurs (which is quite frequent in high-tension systems), corona may develop into a brush and possibly into an arc.

Another danger caused by corona is the possible decay of the insulation and of the conductors. Much has been written on the action of corona in producing ozone, oxides of nitrogen and nitrous and nitric acid, which through a process of oxidation cause a disintegration of almost all insulating materials, and sometimes the production of organic acids. While the action begins on the surface of the insulation exposed to air or air pockets, the gases produced by the discharge may be carried beyond the zone where they are formed and become active elsewhere. It is undoubtedly true that prolonged action of corona results in the deterioration of insulation and, although in a less degree, of conductors; and must therefore be avoided. It must also be remembered that corona produces local heat with all its consequent ill effects.

At this point it is important to note that corona is not exclusively a high-tension phenomenon, but may occur at comparatively low voltages if the distance between conductors subjected to a difference of potential is sufficiently small. This is often the case in the windings of generators or motors where the conductors are insulated well enough to prevent a puncture between conductors or to ground. However, if air spaces exist between conductors or between conductors and ground and the difference of potential be high enough, then the air spaces may glow with disastrous effect to the insulation.

Of course, in high-tension work the possibility of the presence of corona is greater, and for this reason corona is generally considered a high-tension phenomenon. In the case of high-tension transmission lines, a very serious objection to corona comes from high losses. By choosing the proper diameter of the conductor, and by properly spacing the conductors, these losses can be eliminated; and it is possible to design high-tension lines so that the critical voltage at which corona appears on the conductors, and also the voltage at which losses begin, are above the operating voltage. Lately, in some cases, lines have been designed so that the operating voltage is just below the critical voltage of visible corona, but above the voltage at which line losses begin. It is even considered commendable to operate a line close to the critical corona voltage in order to increase the dissipation of energy and the consequent damping of oscillations and smoothing of steep wave fronts in the system. No definite experience has been gathered so far on this point, and it is doubtful whether corona losses are effective in protecting the lines from high-tension impulses and oscillations. Very likely corona losses do not start immediately at the instant at which high potential is applied to the conductor; and furthermore the law by which corona losses increase with the voltage does not give a very steep curve, but a rather mild curve which follows a quadratic law. In other words, there is no sharp elbow in the curve above which the losses increase very rapidly with the voltage, and which could be adopted as the normal operating point of the line. It is true that over-tensions are generally accompanied by high frequency, and that corona losses increase with the frequency, but this proposed application of corona to the damping of oscillations is altogether uncertain and needs investigation.

In like manner it has been suggested to use corona losses for the purpose of limiting the difference of potential at the open end of long unloaded lines. The scheme consists in connecting to the end of a line an auxiliary line of small wire and suitable length, whose losses are small at normal operating voltage when the main line is fully loaded, but as soon as the load drops off and the potential at the end of the main line tends to increase, the auxiliary line restrains such increase by its corona losses, which have become considerable. Here again we find that the law which gives corona losses in function of voltage is too gradual and uniform to lend itself effectively to such application. Furthermore, it has been proved that on direct-current circuits there is a difference between corona on the positive and on the negative conductor,* and other features may be mentioned which are not fully understood.

Notwithstanding the remarkable progress made in the study of corona, it seems that we are not yet ready to employ corona phenomena for useful purposes, and that we should therefore, for the present, endeavor to eliminate them.

The second and third questions, that is to say—Where is corona to be expected, and How can it be prevented?—we shall discuss together. Naturally corona appears where the gradient of the electric stress exceeds the critical disruptive voltage of air. This may happen at the surface of conductors whose diameter is too small, or at the ends of conductors where the high-tension circuit is interrupted. Sharp bends and points are generally the first to be covered by corona. By increasing the diameter of the conductors and by using spheres of large diameter, the electric stress may be reduced below the critical value and corona will be eliminated.

It is known that metallic discs or spheres slipped on a conductor at regular intervals have the effect of increasing the apparent diameter of the conductor so far as corona is concerned. That is to say, each disc or sphere casts, so to speak, a shadow on the conductor, protecting it for a considerable length from corona. It is also known that conductors at the same potential placed in close proximity to each other, or crossing each other, exert a mutual influence, which also has the effect of increasing the voltage at which corona appears. Wire nets are used successfully for this purpose.

*See E. A. Watson's paper before British Association at Winnipeg, 1909.

Figure 1 shows two parallel cylindrical conductors placed at a distance, D, from a grounded plate, and excited at the same potential by a transformer, T. The distance between the centers of the two conductors is d. The voltage of visible corona was observed on these conductors for different values of their diam-

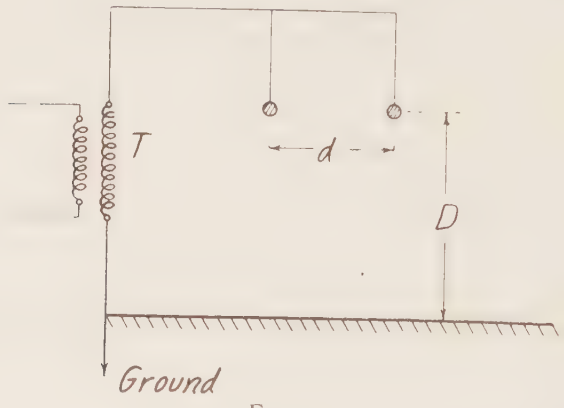


FIG. 1

eter and for different values of d and of D. The following tabulation gives the voltage of visible corona for wires 1/10 in. in diameter, and for D = 15 in. The corona voltage is recorded for the different values of d.

d Inches	KV	d Inches	KV
0.1	40.4	6.0	40.4
0.125	44.2	9.0	38.4
0.25	45.8	12.0	37.5
0.5	40.3	15.0	30.0
1.0	46.3	18.0	36.1
3.0	43.0		

A single wire 1/10 in. in diameter and 15 inches from a grounded plate glows at 33.6 kv. These results are plotted in the curve, Figure 2.

The following tabulation gives the voltage at which corona appears on two parallel wires .064 in. in diameter for D = 9 in.

d Inches	KV	d Inches	KV
0.064	30.0	6.0	27.7
0.125	31.8	9.0	26.4
0.25	33.1	12.0	25.7
0.5	33.6	15.0	25.2
1.0	32.8	18.0	24.9
3.0	29.8		

A single wire, .064 in. in diameter and 15 in. from the grounded plate, glows at 23.4 kv. All these readings were

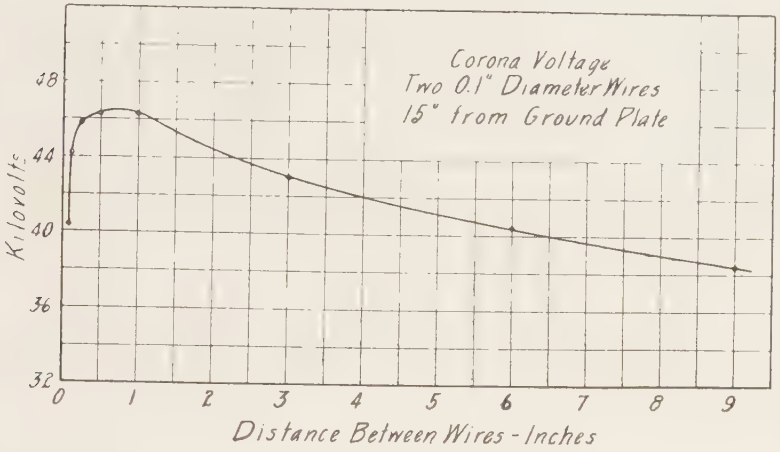


FIG. 2

taken at an average temperature of 25 degrees C., and at an average barometric pressure of 740 mm. These results show

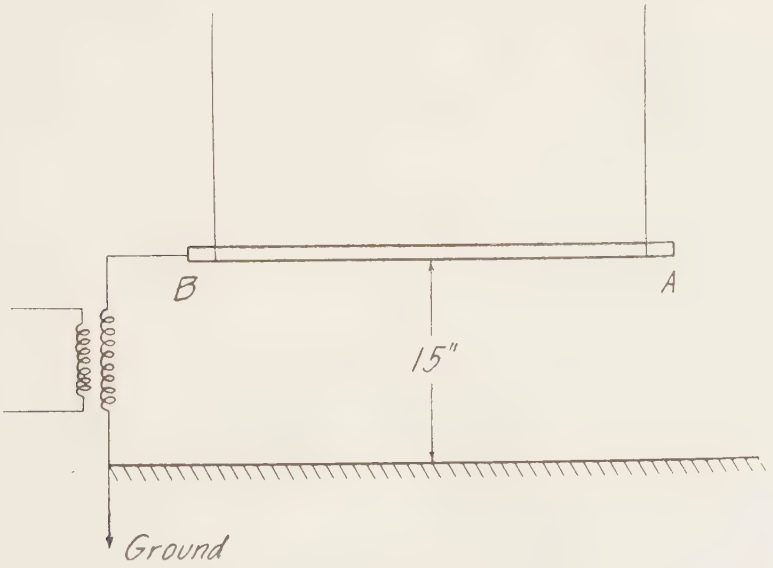


FIG. 3

very clearly the influence exerted by one conductor on the other, and the consequent increase of the critical corona voltage within the range of such influence.

Again, similar results can be obtained by testing the apparatus shown in Figure 3. A rod ¼ in. in diameter is suspended parallel to a grounded plate at a distance of 15 in. from the plate. Corona appears at the end A of the rod at 44.6 kv. The rod is excited from the end B only. From the end A corona extends gradually until at 54 kv. the whole rod, except the end B, is glowing. If the rod is bent sharply, as shown in plan view in Figure 4, corona begins at the bend C at 40.4 kv.

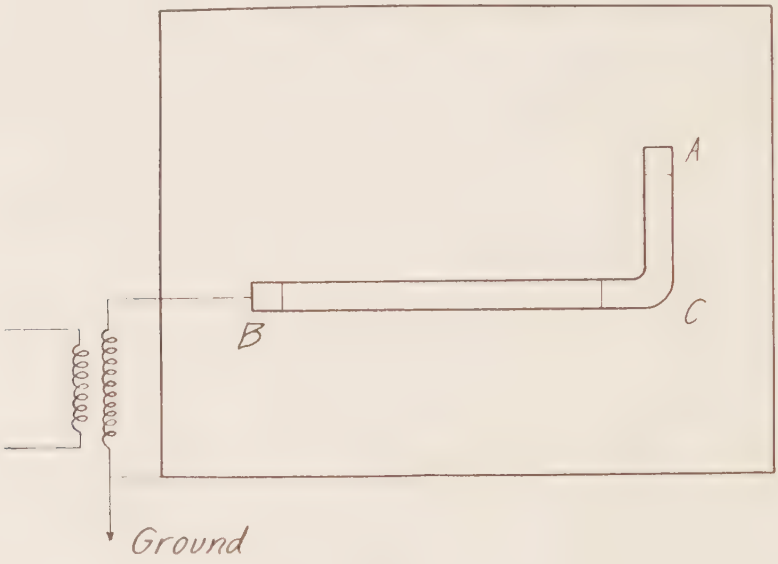


Fig. 4

If now a rod ¼ in. in diameter and in the shape of a T (Figure 5) is tested under the same conditions, corona starts again at the unexcited end A of the rod at 44.6 kv; but at the joint D corona does not appear even at 80.6 kv.

These tests show how by the proper grouping and shaping of conductors, corona can be avoided.

However, corona and brushes occur most frequently at special points where insulation of a certain specific capacity stops, and

another insulating material of different specific capacity begins. A typical case is shown in Figure 6. The arrangement is iden-

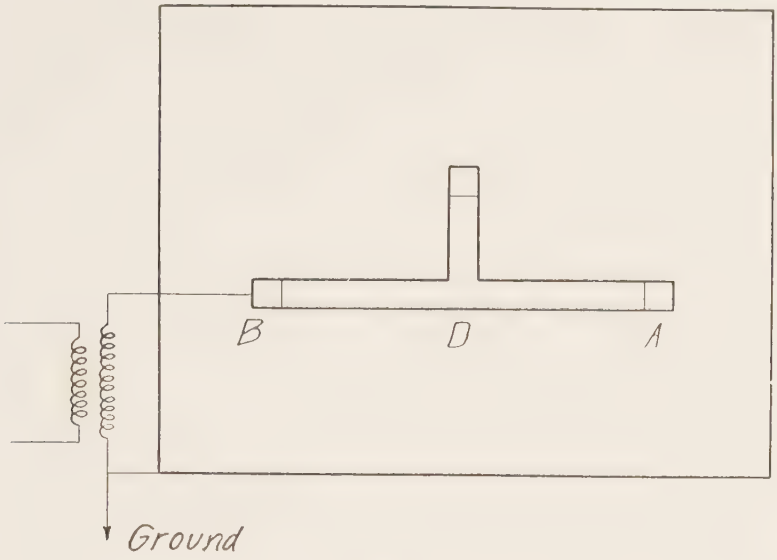


Fig. 5

tical with the one of Figure 3, but insulating tape is wound around part of the rod and the grounded electrode is a cylinder. Along

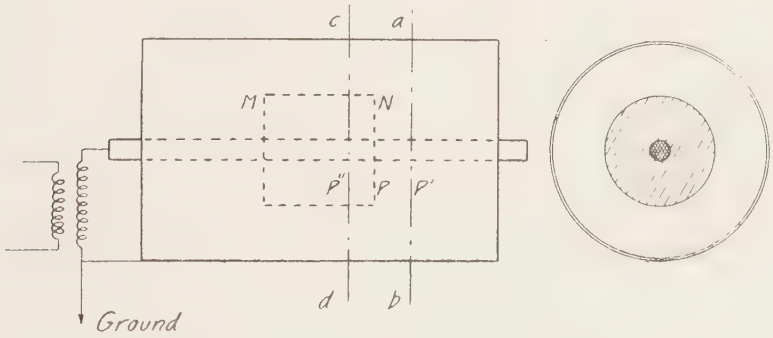


Fig. 6

the planes M and N, which form a division between the tape and the air, corona appears long before any other part of the system

glows; and if the voltage of the rod is sufficiently raised, a breakdown along M and N to the cylinder takes place. In order to fully understand this phenomenon, it may be well to briefly review the theory of a condenser constituted by different dielectrics. Figure 7 shows a condenser made by two parallel cylindrical conductors. The outside radius of the inner conductor is r, and the inside radius of the outer conductor is R.

Let C be the capacity between the interior and exterior conductors per unit length:

$$C = \frac{K}{2 \log \frac{R}{r}}$$

where K is the specific capacity of the dielectric of the condenser. In this case the lines of force of the electric field run along radii

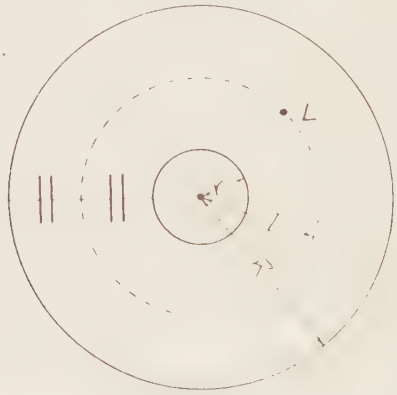


FIG. 7

emanating from the axis of the system, and are perpendicular to the surfaces of the conductors. The equi-potential surfaces are cylinders concentric with both conductors. We will now imagine that the cylindrical equi-potential surface passing through L is materialized and metallic. The presence of this metallic cylinder does not disturb the electric equilibrium of the system, because it coincides with an equi-potential surface.

If we call C′ the capacity between this imaginary intermediate cylinder, and the exterior conductor per unit length we have

$$C' = \frac{K}{2 \log_e \frac{R}{L}}$$

If zero is the potential of the exterior conductor (which is therefore assumed grounded), V the potential of the interior conductor and V′ the potential of the intermediate cylinder, we have $CV = C'V'$ because both CV and C′V′ represent the number of coulombs which are displaced through this system. In fact, the coulombs are obtained by multiplying the capacity of a condenser by the difference of potential across its plates.

We then have

$$V' = \frac{C}{C'} V$$

$$V' = \frac{\log_e \frac{R}{L}}{\log_e \frac{R}{r}} V$$

This last formula gives the value of the potential V′ at any point of the system at a distance L from the axis, when the dielectric of the condenser has the same specific capacity throughout. A numerical example may prove useful. Let us assume that the outside radius of the interior cylinder (r) is 1 in., and that the inside radius of the exterior cylinder (R) is 5 in. We want to find the potential of an imaginary cylinder situated midway between the two concentric conductors; that is to say at L = 3 in. We have

$$V' = \frac{V \log \frac{5}{3}}{\log 5} = .317\ V$$

Then if the exterior conductor is grounded and the interior conductor is at a potential of 100,000 volts, the points on the surface of the hypothetical middle cylinder are at a potential of 31,700 volts. That is to say, when 100,000 volts are applied across the condenser, the drop of potential between the interior conductor and the middle cylinder is 68,300 volts, and the drop of potential between the middle cylinder and the exterior conductor is 31,700 volts. Let us assume now that the specific capacity of the dielectric is not constant throughout the condenser, but that, for instance, the condenser is divided into two parts, one from the interior conductor to the middle cylinder L containing a dielectric whose specific capacity is 2, and another part from the middle cylinder L to the exterior conductor, insulated with air, whose specific capacity is 1.

Then the capacity C′ between the surface L and the exterior conductor is

$$\frac{1}{2 \log_e \frac{5}{3}}$$

The capacity C″ between the interior conductor and the surface L is

$$\frac{2}{2 \log_e 3}$$

We will apply again the formula

$$V' = \frac{C}{C'} V$$

Since

$$C = \frac{C' C''}{C' + C''}$$

We have

$$V' = \frac{C''}{C' + C''} V$$

$$V' = 0.48 \; V$$

If V is again 100,000 volts, the potential V′ of the middle cylinder is now 48,000 volts. That is to say, the drop of potential across the condenser formed by the interior conductor and the middle cylinder insulated by a dielectric of high specific capacity, is 52,000 volts; and the drop of potential across the condenser formed by the middle cylinder and the exterior conductor and insulated with air, is 48,000 volts. The use of high specific capacity as part of the dielectric, has changed the distribution of voltage across the condenser. In the last case mentioned where the dielectric of high specific capacity was used around the interior conductor, the distribution of voltage was made more uniform, and the dielectric properties of the condenser were improved.

Let us now refer back to Figure 6. Along the cross-section *a b* the distribution of potential is the same as we found it on the first condenser which we investigated; that is to say, if the diameter of the outside cylinder is 10 in. and the diameter of the inside conductor is 2 in., we have the following potentials:

100,000 volts on the inside conductor;
31,700 volts at the middle points;
0 volts on the outside conductor.

Along the cross-section *cd*, however, the distribution of potential is different, and is the same as was found in the second condenser we investigated, if we assume that the insulating tape has a specific capacity 2, and is wound around the inside conductor to an outside diameter of 5 in. Along *cd* we have then the following distribution of potential:

100,000 volts on the inside conductor;
48,000 volts on the middle points of the condenser, which points are also on the outside surface of the insulating tape;
0 volts on the outside cylinder.

A point P on the plane N will then be at the same time under the same conditions as the point P′ on the plant *cd*, and as the point P″ on the plane *ab*. The result is that a lateral stress occurs on the planes M and N, which causes an early production of corona along these planes.

Roof and wall bushings, leads of transformers and of

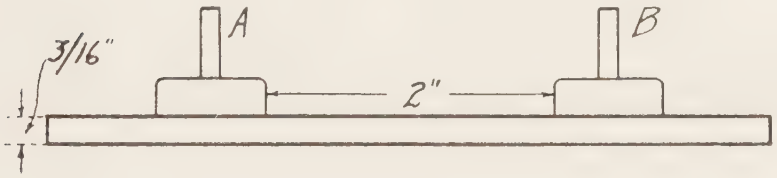


Fig. 8

switches, and all points where bus-bars or conductors are attached to insulators, develop the phenomena just described, and are therefore subject to possibility of corona. A remedy is the use of metallic masses which equalize the potential at the dividing surface between different dielectrics; or cast protecting shadows on the weakest parts of the conductors; or improve the distribution of potential in the dielectric system. For instance, if metal discs are slipped on the inside conductor of Figure 6 against the sides of the insulation on M and N, corona is eliminated at those points.

To show again how these general ideas can be applied to practical purposes, let us take (as shown in Figure 8), a sheet of pressboard 3/16 in. thick, on which are placed two electrodes, A and B. The distance between the nearest points of the electrodes is 2 in. Then we will place the same electrodes on opposite

sides of the sheet of pressboard, so that the distance in air between the nearest points of the electrodes, around the pressboard, is again 2 in. (See Figure 9.) The two systems are both in air, and the question is which of the two will arc over first from A to B when a difference of potential is applied between A and B.

In each system the path of the lines of electric force may be all in air or all inside of the pressboard; or partly in air and partly in the pressboard, but in the second system the lines of electric force, such as *a*, cover a very short distance from A to B through a path composed of air and pressboard. On account of the higher specific capacity of the pressboard, the greater part of the potential along the path is crowded on the air around A and B, with the result that violent corona soon surrounds the electrodes, and gradually develops into streamers around the pressboard and into an arc. The second system is weaker than the first. Tests show

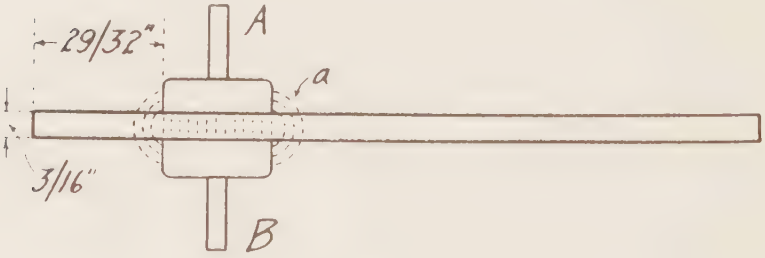


Fig. 9

that the first system arcs over at 116 kv between A and B, whereas the second system arcs over at 68 kv between A and B.

These examples covering simple condensers are intended to show in a general way the methods pursued in dealing with the complex condensers used in high-tension systems. As a general conclusion we may say that to locate the dangerous parts of a system and to avoid corona is not a difficult problem for the voltages used at the present time. In fact, all the systems operated at the highest voltages are exempt from corona troubles.

The highest potential used nowadays in commercial operation is 140,000 volts, and it will be interesting to review briefly some of the principal features of the system of the Au Sable Electric Company, which is the only one operated at this voltage.

Figure 10 is a map of the system as it is at the present time. The power-house, containing three 3000-kw generators and three 3000-kw transformers, is situated on the Au Sable River, and the line is 125 miles long. The Zilwaukee substation is 85 miles

FIG. 10

from the power-house, and 40 miles from the Flint substation. In the future, the system will be tied-in to other systems at Flint to form a part of Mr. J. B. Foote's Michigan installations.

Figure 11 gives the arrangement of the three conductors which constitute the three-phase line.

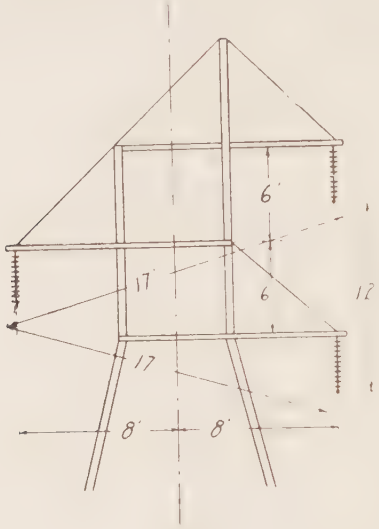


Fig. 11

Figure 12 shows the standard tower of the system; there is no grounded cable to protect the line. The line insulators are

Fig. 12—Standard Tower

of the suspension type and have 10 discs in series. Each line conductor is a 0 seven-strand copper cable without hemp center. Each strand is of 1/8 in. diameter; the outside diameter of the conductor is .379 in. This system has been in operation since the beginning of the year, and has proved satisfactory and successful in every detail. At normal voltage the substations are entirely free from corona, and the line is somewhat noisy at the middle of the spans, but no luminous discharge can be seen on the conductors.

If we apply to this line the formulæ developed by Mr. F. W. Peek, Jr., we obtain the following results:

Disruptive Critical Voltage e_0

$$e_0 = 2.302\, m_0\, g_0\, r\, \delta \log_0 \frac{s}{r}$$

where the same symbols are used as in Mr. Peek's paper presented to the annual convention of the American Institute of Electrical Engineers in Chicago, in June, 1911.

m_0 (a constant) = .87

g_0 (disruptive gradient of air) = 53.6 effective kilovolts per inch

r (radius of conductor) = .189 in.

δ, the density of air taken at 20° F. and 29.5 in. barometric pressure = 1.1

(The line runs at a practically constant altitude of 500 ft., and therefore the barometric pressure is taken as 29½ in.)

s (average spacing of conductors) = 174 in.

We have then:

e_0 = 66.5 kilovolts to neutral.

Corona Losses p

$$p = \frac{k}{\delta} \cdot f \sqrt{\frac{r}{s}} \cdot (e - e_0)^2\, 10^{-5} \text{ kv per mile of single conductor}$$

In our case:

k (a constant) = 552

f (the frequency) = 60

δ, r, s, as before.

$p = 985\, (e - e_0)^2\, 10^{-5}$ kw per mile of single conductor.

$p = .0295\, (e - e_0)^2$ kw per mile of three conductors.

Applying this formula we obtain the following results:

KV Between Lines	KW Loss Per Mile 3 Conductors	KV Between Lines	KW Loss Per Mile 3 Conductors
115	0.	155	15.7
140	6.2	160	20.0
145	8.5	165	24.0
150	11.8	180	41.5

These results are plotted in the curve, Figure 13.

The line has been in operation for such a short time that no accurate measurements of losses have been made. It is intended to perform some very accurate experiments on this system as soon as conditions will allow, but at the present time only a few approximate readings of corona losses have been taken. When the full voltage of 140 kv is held at the power-house and the line is unloaded, the voltage at the end of the line in Flint (where three 3000-kw step-down transformers are connected to the circuit)

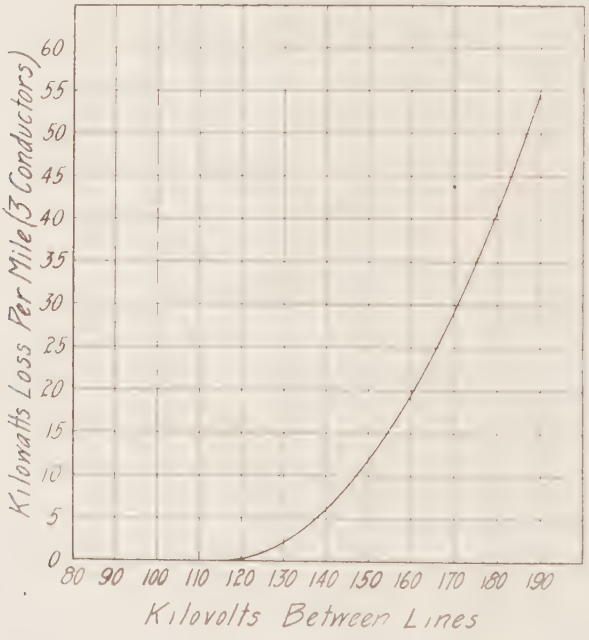


Fig. 13.

is 165 kv. Under these conditions the average loss per mile as given by Figure 13 is 15 kw. The readings actually taken show losses of from 15 to 20 kw per mile under these same conditions. When the line was first put in operation the losses were still greater and gradually decreased during the first half hour. This phenomenon, which has been pointed out in Mr. Peek's paper, is due to particles of mud, dirt, sleet, etc., which may be on the conductors, and which are eliminated after the voltage stress is

left on the conductors for a short time. If a uniform voltage of 140,000 volts is maintained throughout the system, the calculated losses are reduced to about 6 kw per mile.

Again, if 140 kv are held at Flint by lowering the voltage at the power-house to 120 kv, an average loss of 3 kw per mile should be expected. This figure has also been obtained by actual measurements.

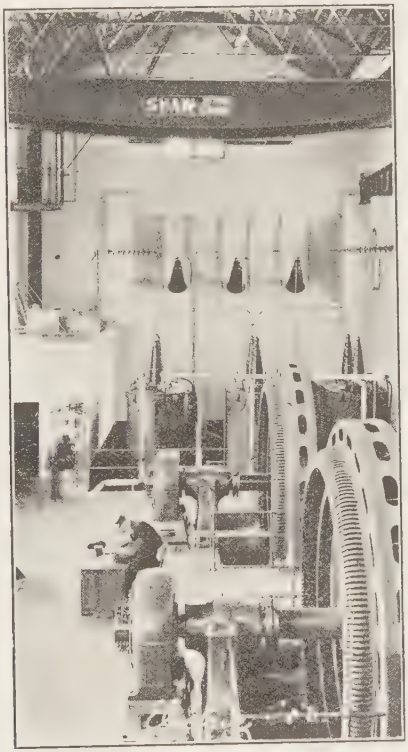


Fig. 14—Interior of Power House

When the system is once in full operation, and power is supplied to it from the power-house and from Flint, it is expected that the voltage will not exceed 140 kv at any point.

The curve, Figure 13, is, of course, a theoretical curve, and it is known that at voltages near the disruptive critical voltage, the actual losses deviate from the quadratic law by an amount

which cannot be conveniently calculated. This is especially true in the case of new conductors.

Visible Corona

At 20 degrees F. and 29.5 inches barometer, the voltage at which local corona appears on the conductors figures at 134 kv and the voltage at which complete corona will appear on the con-

Fig. 15—Zilwaukee Substation

ductors figures at 155 kv. The operating voltage of 140 kv is, therefore, just below the critical voltage of complete visible corona, and this explains the faint noise which is heard on the middle of the spans along the line.

Figure 14 is a view of the interior of the power-house.

Figure 15 represents the Zilwaukee substation, and Figure 16 shows how the high-tension conductors enter the Zilwaukee

FIG. 16—ZILWAUKEE SUBSTATION—ENTRANCE BUSHINGS

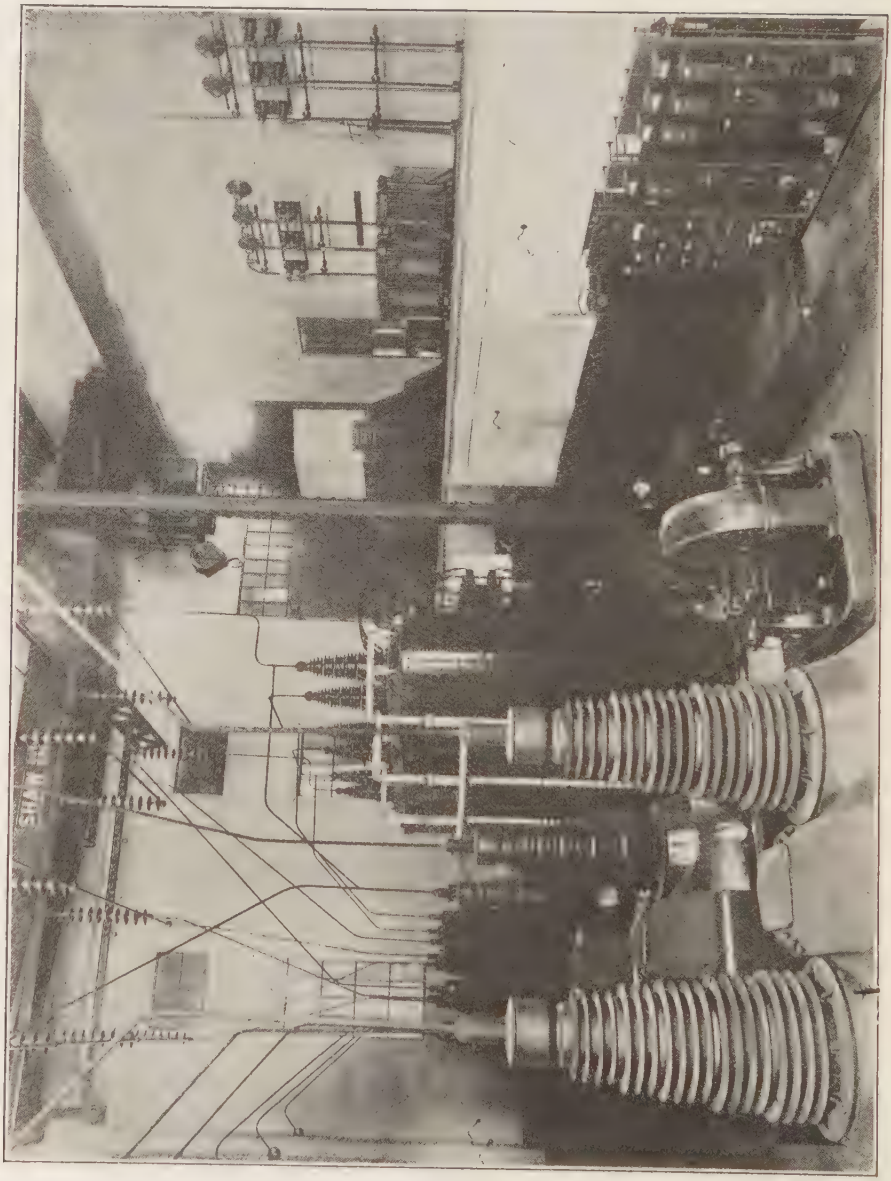


FIG. 17.—INTERIOR OF ZILWAUKEE SUBSTATION

FIG. 18—ZILWAUKEE SUBSTATION—HIGH-TENSION CONNECTIONS

FIG. 19—SUSPENSION INSULATOR

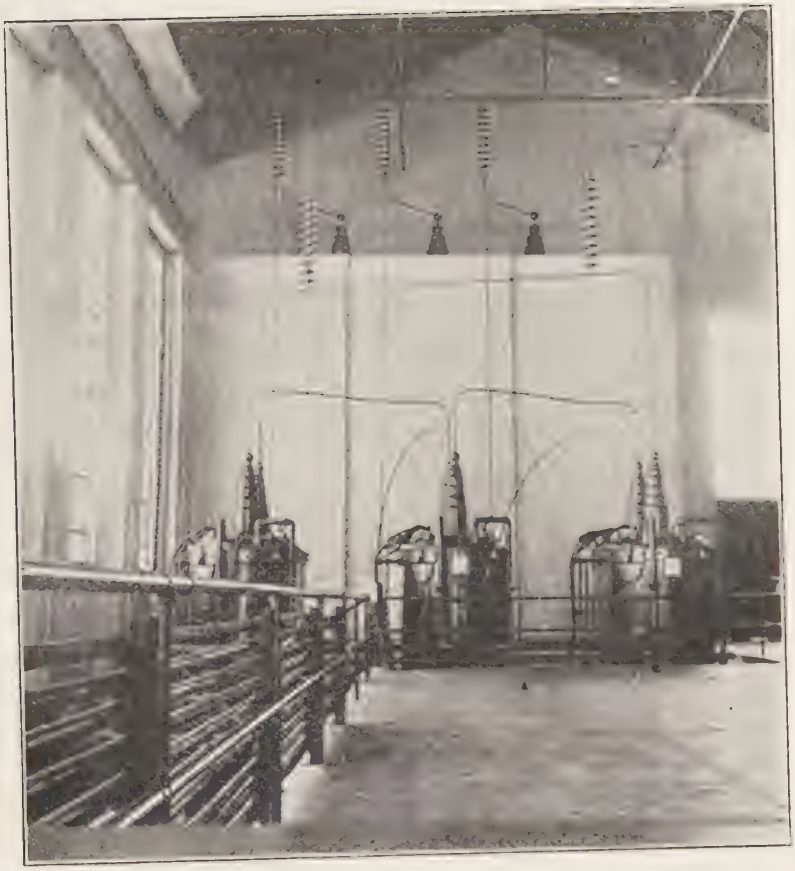


FIG. 20—FLINT SUBSTATION—HIGH-TENSION CONNECTIONS

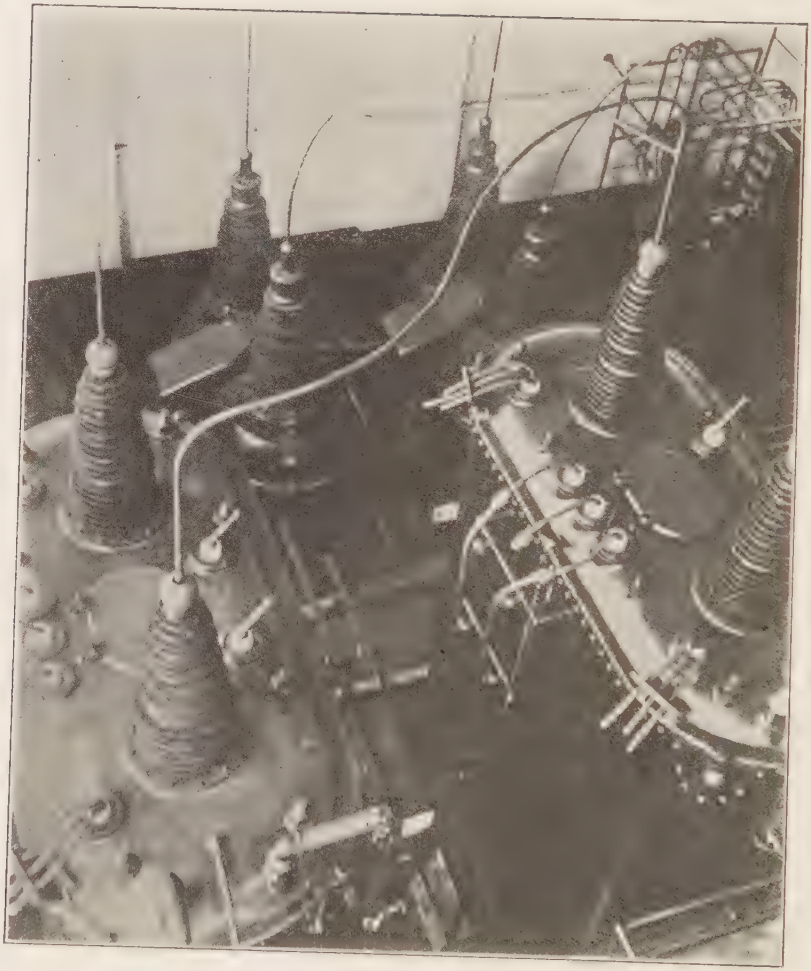


FIG. 21—FLINT SUBSTATION—TRANSFORMERS AND SWITCHES

substation. The conductors, after entering the substation, go through oil-switches to the high-tension bus-bars; then from the high-tension bus-bars through another set of oil-switches and wall bushings, they pass out of the substation. To the bus-bars are connected three 3000-kw transformers through oil-switches. This makes a total of nine oil-switches, six entrance bushings and three high-tension bus-bars, as shown in Figures 17 and 18. These pictures show four high-tension conductors hanging by suspension insulators from the roof of the substation. Three of these are high-tension bus-bars, and one is the long delta connection of the transformers. The suspension insulators used in the stations are identical with the tower insulators and are shown in Figure 19. The bushings of the transformers and of the oil-switches, and the entrance bushings are all of the same type and filled with fluid insulating compound. The bus-bars and the cross-connections in the substation are made of 1¼-in. iron tubing. The terminals of the bushings, the ends of the bus-bars and the points where the suspension insulators support the conductors are protected by large spheres to eliminate corona.

Figures 20 and 21 show the connections at the Flint substation. It is interesting to know that when the lights of the Flint substation were turned out in order to detect any possible presence of corona on the conductors, it was found that two spots were glowing on the top of each transformer. The lights were turned on and it was discovered that corona was glowing at the terminals of the 370-volt winding with which every transformer is equipped, and which is intended to operate rotary converters. At present the winding is open in each transformer, and, therefore, subjected to the high electrostatic induction from the high-tension winding. Corona will, of course, disappear as soon as the 370-volt windings of the three transformers have been connected in delta and local induction from the high-tension windings eliminated.

A glance at the arrangements of the apparatus and of the conductors in the stations reveals the great simplicity and effectiveness of this installation. The system is delta-connected throughout, and high-tension switches have been operated quite frequently without any trouble. This first attempt at 140,000-volt operation is so far a decided success, and justifies universal confidence in what may be accomplished by skillful engineering.

DISCUSSION

MR. A. J. BOWIE, JR., San Francisco: I would like to ask if any experiments have been made on the corona loss under oil, such as would occur in transformers or oil switches?

MR. F. D. NIMS, Vancouver, B. C.: My experience has been confined to 85,000 volts and we have had no trouble with corona. We were not anywhere near the critical point. I want to get the experience of some of the other gentlemen.

MR. RUSHMORE: Corona phenomena have become more important as we have advanced to higher voltages. The phenomenon of corona is very closely associated with some of the most interesting physical laws dealing with the conductivity of electricity through gases, which latter has been the subject of scientific study for many years. Air, which is the gas with which we usually have to deal, becomes a conductor under certain conditions, when it is said to be ionized. Simply expressed, this means that some of the constituent gases are in the atomic form. The breaking up of the molecular structure into atoms requires a certain amount of electrical stress. An electrical stress and mechanical stresses are very closely related when a mechanical force is exerted upon a charge of electricity in a static field. Whenever the electrical stress is raised above a certain limit the molecules of the air are broken up into atoms, and the air thus becomes a conductor. This result may be brought about in a number of other ways—by passing the air over an incandescent body, by bubbling it through water, by bringing it under the influence of certain rays of light. Thus, wherever the stress around a wire becomes sufficient the molecules of air surrounding this wire are broken up into atoms, and the electricity from the wire is conducted into a cylinder surrounding this wire. The diameter of the cylinder is increased until a point is reached where the potential gradient of the electric field does not exert a force sufficient to overcome the forces holding the atoms of air together. With the increase in voltage the diameter of this cylinder necessarily becomes larger. The amount of power absorbed is in most cases comparatively small. This is, for some reasons, unfortunate.

The suggestion has often been made of protecting power houses from line disturbances by using wires of a diameter to bring about a condition which is approaching corona; thus, any

decided increase in voltage on the line, due to the approach of a charge of electricity, would bring about a condition of corona discharge, and a certain amount of the energy would be dissipated in the resistance of the air. The exact protective value of such a feature has not as yet been determined. That it would be of some protection there can be no doubt, but just how much is at present unknown.

There is a very nice point of distinction between the condition of an electrical field which breaks down the oxygen molecules, forming ozone, and a stronger field which breaks down the nitrogen molecules, forming nitrous oxide. A nitrogen molecule requires greater stress for its disruption, and therefore a properly designed ozone machine will give no nitrous oxide. This nitrous oxide forms nitrous and nitric acid, and thus becomes a conductor.

The effect of corona loss is important in limiting the size of wire which can be used for power transmission work, and one of the factors to be taken into consideration is the altitude, as the pressure of the air decreases with higher altitudes and corona is formed at lower voltages, as the experiments carried on by Mr. Peek in conjunction with Dr. Steinmetz show. It also varies with a number of other conditions which have been brought out. The practical bearing of this is in the design of interior wiring of substations and elsewhere, where care should be taken to see that at no point is the diameter of the conductor such that any considerable corona appears.

With regard to the question brought out by Mr. Williams, the explanation of the influence upon vegetable growth of the presence of electrically charged conductors has not been entirely clear. It may be that ozone is formed, and ozone we know is stimulating to animal life, and probably would be to plant life also. It seems impossible that under the conditions which have existed no measurable amount of nitrous oxide could be formed. The explanation that plants are affected by the presence of ultra-violet rays appears to be as yet unproved, and, so far as I know, the real reason for this result, if it actually exists, has not been entirely explained.

My object in bringing up these different points is to open the discussion on the ground so thoroughly covered in Mr. Faccioli's excellent paper on the subject.

MR. HAYES: There are one or two points only that occur to me. In looking at the photographs of the 140,000-volt installation in Milwaukee, I notice that there seem to be no disconnecting switches between the oil circuit-breakers and the bus-bars. I want to find out whether there were any supplied, and if so whether any corona has been noticed around the jaws or sharp points of these disconnecting switches in actual practise.

In this connection I might say that in one of the 110,000-volt, step-up transformer stations at Niagara Falls, the disconnecting switches have their plates made out of tubing. The jaws, however, are usually flaring, and in actual practise there has been no noticeable corona at these jaws.

The overhead bus-bars are made of copper tubing and no corona is noticeable except at the end of one bus that extends quite a distance beyond the nearest tap. One rather peculiar thing is that if a certain disconnecting switch connecting to the bus is closed the corona disappears. Evidently the slight additional capacity introduced by connecting the switch is enough to cut out any corona. At that station they originally attempted to make very large bends in all of the tubing. They actually found, though, that if they made bends of from about 12- to 18-inch radius they had no trouble from corona at 110,000 volts.

MR. F. M. KERR, Butte, Mon.: We have in our Butte substation some effects that I have not seen anywhere else. This station was built some six or seven years ago when we did not know much about insulation, and was built in such a manner that it has been very difficult to revise. We have been running along with rather poor insulation, although we have not had any trouble particularly from it; in fact, we have never had but one breakdown in the station. We are using an insulator that is known as the Thomas 3003; I don't remember the exact dimensions of it, but it has only one petticoat on an iron pin and is used on 50,000-volt bus-bars placed in concrete chambers. There has always been a great corona discharge there, a lot of noise, and a strong ozone smell in the room. After the service had been on approximately a year, it was noticed that where the bus wires were tied with number ten tie wire to the top of the insulators, the ring surrounded by the tie wire would begin to turn white and the glaze disappear from the insulator. That belt has spread and spread, until now the old insulators are

entirely bare of glaze near the tie wires. They are perfectly white and the tie wires and all the bar wires in the bus chamber are very black. Even the concrete walls (the clearance is 18 inches) show a distinct change of color. In these chambers there were a few bricks, and the faces of the bricks have been eaten off. Ours is a sandy country, very dry a great part of the year, and I believe that this erosion is due to the bombardment of particles of sand. I would like to know if anybody else has ever seen anything of the kind described.

The new Great Falls Power Company lines are 130 miles long, using number one conductors and six ten-inch suspension discs. It has been noticed that during a rainstorm the increased loss on the line is approximately 1000 kilowatts. While there is never any demonstration of corona that can be seen, we assume that to be the cause of the increased loss.

One of the gentlemen spoke of disconnecting switches. We have a phenomenon similar to the one he mentioned. The taps from the bus to the oil switches and transformers are all three-quarter-inch iron pipe; the elbows being short and at right-angles. At no point on these is there any corona except at one disconnecting switch, and this switch has a corona discharge all the time. We went so far as to take it down and change it, putting in new switches and different types of switches. It made no difference, however, there was always corona and a strong hissing noise.

Mr. Nims: May I ask the gentleman what size pins he uses in that construction?

Mr. Kerr: Thirty-inch locust pins, treated with paraffine.

Mr. M. E. Cheney, Seattle: I would like to ask for information concerning a rather peculiar phenomenon that we are told occurs over in the Big Bend country east of the mountains, a rather dry country. Preceding a storm oftentimes there are cases where the fuses in branch circuits and in various houses have been burned out, and also cases where lamps have been burned out. Static effects have been noticed also on pendant cords. I would like to have an explanation of that feature, if it is possible to give it. I think the voltage is 60,000.

Mr. C. M. Stone, Schenectady: One of the questions raised by a previous speaker was about the extent of the appearance of corona in oil. As corona means a stress of air and the breaking up of the molecules of air, I should not expect any corona effect

in oil unless there was a considerable amount of occluded air in the oil, and even then I think it would be difficult to find it because the potential which is necessary to produce ozone or corona would probably not be sufficient to break down the oil.

Mr. Hayes spoke of disconnecting switches and the appearance of corona. Under certain conditions I should expect corona to appear on some types of disconnecting switches, but I do not see that it would do any harm, as the action would be so slow that it should not affect any of the apparatus seriously. I should expect trouble from corona where we take a conductor through a porcelain insulator imbedded in a concrete or a brick wall. Under those conditions corona would probably appear, as the potential gradient is such that the entire potential is concentrated on the thin film of air between the conductor and the porcelain insulator. The air is the poorest conductor and consequently would be broken down. To protect against that if a conductor which snugly fits the inside of the insulator were used corona would not appear, or if the inside of the insulator were copper plated and connected solidly to the conductor going through the tube then the entire potential would be concentrated on the porcelain which is supposed to be the insulator, and we would not have corona. The only case where we would expect trouble from corona without this arrangement would be when we use a rubber or varnished cambric insulated cable through the porcelain insulator, as that would be affected in time by the formation of ozone and its insulating value would be destroyed. As long as we have a proper sized porcelain insulator there, however, we should expect no trouble, but if the cable were drawn out, put in some other place and used for another purpose we might expect breakdown at that point.

I think the old conception of corona is that it is a high-potential phenomenon. It is not. Corona in 2300-volt apparatus is not unusual and it is easy to produce it at very much lower potentials. It is a question of stress purely, and therefore in the design of apparatus and in the location of apparatus, every care should be taken to avoid any exceedingly high stress at any one point, if we are going to depend on any insulation value at that point.

Mr. Kerr brought up a question of the increase in loss on transmission lines of about 1000 kilowatts at certain times. That is a phenomenon similar to those we were able to reproduce

in our experiments on the high-tension line in Schenectady. The losses increased very rapidly during rainstorms or snowstorms and Mr. Peak in his paper before the American Institute of Electrical Engineers at the last convention gave a table showing what this increase is under different storm conditions. Mr. Cheney brought up the question of trouble and the blowing of fuses at a time when there is considerable atmospheric disturbance going on. It is probable that these atmospheric disturbances induce in the circuit other disturbances which traverse the line and thus build up high potentials at certain points, causing the blowing of fuses. This is similar to the effect of a severe lightning storm when, without a line being struck, almost every telephone arrester will act and fuses will be blown. In fact, we had one storm in Schenectady last year, in which about 5000 lightning-arrester fuses were blown and not a single line was struck.

Mr. Bowie: When I spoke of corona loss I did not refer to the phenomena which appear in air, the visible phenomena, but to the breaking down of the oil directly around the conductor; in other words, the stress is of such value that there would necessarily be a breaking down in the insulation. In transformers the distance between conductors is necessarily very much less than in air and the conductor is likely to be of much smaller diameter also. I referred not so much to the loss as to the possible deteriorating effect of any such action on the oil, and particularly perhaps where the light enters the oil. I would like to know if there has been any observation or test made of such action?

Mr. Rushmore: I believe I can answer Mr. Bowie's question by saying the phenomenon has been observed. It is known that some such action takes place, that you can get electrical stress in oil above the breakdown point. The limit is pretty well known above which you ought not to go, but just what happens when you pass above that limit has not yet become exactly known. It is one of those things waiting for investigation.

The Chairman: Is there any further discussion? If not, we will proceed to the next number, the Report of the Committee on Protection from Lightning. Mr. S. D. Sprong, the Chairman of this committee, is absent, and Mr. H. B. Gear, of Chicago, will read the report.

REPORT OF COMMITTEE ON PROTECTION FROM LIGHTNING

As a result of a meeting and subsequent correspondence, your Committee on Protection from Lightning has given particular consideration to the question of ways and means to carry on the work that naturally comes within its scope. The question was considered also in the light of the past work of committees on this subject, and what application the methods already adopted by them may have to the further investigation of this subject.

It was the general feeling that in view of the knowledge and data so far gained of the phenomena of lightning and the present stage of protection from it, further work along established lines could yield but little additional material of any value. For a few years only has anything relatively definite been known regarding protection from lightning, and until recently, the collection and tabulation of reports on this subject have been the only available means of securing information. The method was valuable also in indicating lines of experiment that have recently yielded some very important information.

The committee, however, does not assert that knowledge of actual experience is of little further value; quite the contrary. The difficulty is that this branch of the work has now reached such a stage that reports as they are usually made up by the different companies have little in them of present-day value. The information that can be given by operators of electrical systems is very much limited by the lack of recording devices. The most pressing need at this time is for trained observation and analysis by experts of the records and methods collected by the several companies for their own use.

It is the feeling of the committee that this subject has reached a stage where a definite and continuous policy should be undertaken which would make the information obtained and analyzed under expert direction, of particular worth for the practical suggestions that may be drawn from it, and the valuable comparisons that may be made as the committee's work progresses. There are a number of important problems before transmission companies to-day which are still without solution.

One of these problems is the subject of overhead ground wires. Many thousands of dollars have been spent in overhead ground wires and much more expense will be undertaken because of the fact that these wires are recommended generally, and yet at the present time there is little definite information regarding their value or whether by slight additional expense they might not be very greatly improved.

In view of these considerations, the committee has thought it desirable before proceeding along lines more or less familiar, to bring its views to your attention, with the recommendation that an expert be employed for the purpose of visiting certain representative systems as selected, to analyze their reports, offer suggestions as to methods of tabulation and observation, furnish blank forms, and to make direct observations on the systems under investigation.

As there is very little information on which to base an estimate of the time required or the expense involved, the committee would suggest an appropriation of $2,500, to be expended at its discretion for the purpose suggested above. If, however, the Executive Committee does not feel at liberty to appropriate this amount of money for the use of a particular committee, we suggest that the committee be given authority to bring the matter to the attention of the member companies, explaining the objects in view and the results it is endeavoring to accomplish, and to ask from them contributions to a special fund for the furthering of this work.

Each year's delay in beginning this important study means so many thousands of dollars more expended for problematical conditions. A very nominal sum invested by each of the interested companies could start experiments which would finally give definite information regarding the effects of atmospheric disturbances.

This line of investigation applies particularly to the transmission companies; most of them, having to do with transmission problems, realize the importance of the work remaining to be done in the protection of their systems, and the very limited utility of further work along the old lines. We believe that the results of committee work of the character proposed would have many times the value to transmission companies of such sums of money as they might contribute.

Before undertaking any work on the lines suggested above, we wish to draw particular attention to the fact that this departure in committee work can yield valuable results only if it be continued from year to year for a considerable period of time. There is, of course, no way for the present officers of the Association to insure continuity of this kind, but we strongly urge the inauguration of the work if the present officers believe with us, that a knowledge of the objects to be obtained and of the methods to be employed will in all probability secure the commendation and support of succeeding administrations.

Respectfully submitted,

Committee
- S. D. Sprong, *Chairman*
- Ralph D. Mershon
- E. E. F. Creighton
- L. L. Elden
- P. M. Downing

The Chairman: The report is now open for discussion. We will again ask Mr. Rushmore if he will be kind enough to make a few remarks.

DISCUSSION

Mr. Rushmore: I do not want to carry on a discussion, but will merely try to open it up by bringing out some of the points for consideration here.

As you know, for a great many years experiments were carried on with the multi-gap lightning arrester. Pieces of paper were inserted in the spark gap and records of discharges were obtained from certain holes in the paper. Such records and photographs of them have appeared in the Institute Proceedings showing the size of the hole, the number of holes and the number of leaks over which the discharges took place.

Information of this kind is very interesting, but very incomplete. You can with a spark gap get a discharge over a piece of apparatus that has absolutely no protecting power. All manufacturing companies and all others concerned with lightning arresters at one time used resistance in series with the arresters.

We had to; that was the only thing we knew of to limit the dynamic currents when discharging. As we continued to study the subject we learned that such resistances limited very much the discharge capacity of the lightning arrester.

A considerable amount of experimental work has been carried on. After the first type of arresters came the graded shunt arrester which is, of course, entirely different. The last arresters of this type afforded a good, but not complete, protection and would not stand up under arcing. And so while the multi-gap lightning arrester is to-day a good protection, so far as it goes, it is necessarily an incomplete arrester. The aluminum cell which has been slowly developed is very much better protection. You can take an aluminum cell lightning arrester and shunt it around the insulation, and you cannot by any possibility puncture the insulation. The aluminum lightning arresters which are put out on transmission systems are quite expensive and their number must be limited by the amount the company feels justified in spending. They have an infinite discharging capacity and you cannot get up a disturbance on the system which will not go through the arrester. It is by far the best thing there is for lightning protection.

There is another and very different subject pressing for consideration and now is an excellent time to bring it to the attention of the Association. It is really a subject for the individual men in these great operating systems to study. That old method of recording lightning discharges was, as I have said, interesting, but decidedly limited. A few transmission men are now beginning to make definite experiments. They have recording apparatus on the systems. They are using the oscillograph and they know pretty well what takes place when some of these phenomena of lightning occur. Of course they cannot register all of them on the oscillograph, nor can they keep track of all of them with recording devices, but it is possible to come very close to it. It is highly desirable that a certain amount of expert ability be put on these systems. The problems are far beyond the capacity of the average employees of manufacturing companies. Each big system should really have a lightning-arrester expert of its own, a man capable of installing all of this special and recording apparatus, and who, when not caring for the lightning arresters and other protective apparatus of the

system, could be experimenting, watching, reading records and finding out what is going on over the system at different times under different conditions, when and what rises of voltage occur, etc., etc.

Mr. Nims spoke just now of the appearance of static electricity on the wires before rain comes. When a heavily charged cloud passes over a transmission line, the ground below the cloud will assume an electric static charge corresponding to the opposite charge of the cloud, and the line conductors, being insulated and raised a distance from the ground, will assume a charge higher than that of the ground. Any equalization of the potential distribution of the cloud, most commonly caused by lightning flashes in the cloud itself or between different clouds, will require a change in the electro static charge of the line conductors corresponding to the changed potential difference between the ground and the cloud. The static charge thus set free on the line will rush as an impulse or wave along the line. Such disturbances occur mainly when rapid condensation of moisture takes place in the clouds, as before a rainfall.

Take the matter of a ground wire. Thousands—hundreds of thousands of dollars—have been spent in overhead ground wires, because general, although sometimes quite vague, experience indicates that they are a help, but how much of a help nobody knows. We have an experimental transmission line in Schenectady and can carry on some work there for this particular purpose, by installing the ground wire in different positions and by installing a different number of ground wires. With a wireless set or something like that in close proximity, electrical disturbances can be set up and the voltage on the ground wires and on the other line or lines measured. In that way we shall determine, after a fashion, the protective power of the ground wire, but the great operating companies have the real thing, actual conditions, and it seems to me that this research should perhaps be taken up by the Association or in conjunction with the Association and we shall then be in a position to make very much more rapid advances in the matter of protection for transmission systems. Of course a great deal of this is being done at present, but the country is large and there are many systems installed. It is impossible for us to make without co-operation the progress we should make with it, as I have outlined.

I would like very much to hear discussion as to the possibility of getting together to carry on the work.

Mr. Gear: The recommendations made by the committee with reference to the employment of some one person whose duty it would be to gather and assimilate data from all parts of the country of different conditions on different systems, appear to offer a very definite and straightforward plan for securing results. This the previous committees have found it very difficult to do because of the necessarily meagre information they were able to get by correspondence. Just how this should be carried through I am unable to say.

It seems to me, however, there is one phase of the subject which the committee has quite overlooked and which concerns perhaps more members of the Association than the ones which they have presented. The report deals entirely with the protection of transmission lines, these lines being watched for the purpose primarily of guarding against interruptions to service, due to the failure of insulators and the occasional damage of substation apparatus. The other phase of the subject, to which previous committees have given considerable attention, is the protection of distribution lines, in which the problem is entirely different. There it is not alone the problem of protection of apparatus and insulators, but of line transformers and distributors throughout the whole length of the line, and on its various branches and ramifications. Some of the larger companies have been keeping records for several years past on the rate of loss in transformers, and some very definite experiments are in progress in Chicago with reference to the protection of circuits with different makes of lightning arresters, one entire group of circuits being completed with one kind of arrester, another group with another, and still another with a third. A 3-phase circuit is equipped with three types of arresters, one of each make on each phase, and other circuits have a spacing about twice as close as the average spacing which has been standard throughout the system. Now it is going to require several years to accumulate data as to the effect of that sort of experiments, and that data should be supplemented by other companies having 2-phase 4-wire, and 3-phase 3-wire systems, so that there may be some data accumulated regarding the other sources of the distributing systems as

well as the 4- or 3-phase which we happen to be operating in Chicago.

I believe, therefore, that this recommendation should carry with it some provision for the study and collection of data regarding protection of distributing systems, where the amount of money involved in transformer investment is perhaps greater, taking the country over, than the amount of money invested in transmission lines. Although the transmission-line problem, as I say, is protection of the continuity of service rather than protection of the apparatus itself, the distribution problem is, of course, also one of continuity of service, because the better we protect the line transformers the better service we can give the customer.

Observations have been made in several of the larger companies for two or three years past, and the Chicago company has records of its transformer burn-outs for nearly ten years past. If this data could be gathered together from all of the companies and turned over to some one person who would make a comparative study of it, something could be worked out which would enable us to decide whether we ought to space our lightning arresters on distributing lines 1000 or 1500, 2000 or 3000 feet apart. As it is now we are following a more or less blind standard. We do not now whether if we use twice as many we would have as many losses, whether if we use half as many we would have double the loss. It is an economic problem to strike a balance between the loss in transformers and loss by depreciation of lightning arresters, one which can be worked out only after a series of years of observation, because everybody knows their losses are worse some years than others, and it would be necessary to have observations for a series of years in order to strike a fair average.

THE CHAIRMAN: Mr. Gear, do you care to put before this meeting a resolution relative to the scope of the committee's work?

MR. GEAR: I do not know that I am prepared to do that, Mr. Chairman. I am not a member of the committee and I was asked only to present the paper this afternoon.

THE CHAIRMAN: It will be perfectly in order if you care to do it.

Mr. Gear: I would move you, Mr. Chairman, that the recommendations in this report be presented to the Executive Committee with the endorsement of the Power Transmission Section.

The motion was put to a vote and unanimously carried.

The Chairman: We will now have the report of the Nominating Committee.

Mr. H. H. Scott, New York City: Mr. Chairman, your Nominating Committee wishes to recommend to this Section the election of the following officers for the ensuing year:

Mr. W. A. Ryerson, of Duluth, Chairman.

Mr. D. B. Rushmore, of Schenectady, First Vice-Chairman.

Mr. Paul M. Lincoln, of Pittsburgh, Second Vice-Chairman.

Mr. Farley Osgood, of Newark, Secretary.

We also recommend that an executive committee of nine be elected. I wish to state in this connection that we have aimed to give the western portion of the country, which contains a great many hydraulic companies, a good representation, but it was recognized by the two western members of the Nominating Committee that it is necessary to have a majority of the Executive Committee in the east in order to transact business. We therefore recommend that the following western members be elected: Mr. J. A. Lighthipe, Los Angeles; Mr. H. A. Lardner and Mr. P. T. Hanscom, San Francisco; Mr. D. L. Huntington, Spokane.

The eastern members we recommend are: Mr. H. T. Porter, New York City; Mr. J. F. Vaughan, Boston; Mr. P. G. Gossler, New York City; Mr. F. B. H. Paine, Buffalo; Mr. W. R. Thompson, Chicago, and Mr. R. D. Mershon, New York City.

This is the unanimous recommendation of the committee.

It was moved, seconded and voted that the report of the Nominating Committee be adopted.

Mr. Doherty, New York: Mr. Chairman, may I say one word in relation to the report of the Nominating Committee? A question has come up as to the part the manufacturer should play in the proceedings of the Association. I regret that there has been some fear that the manufacturer would be given a prominent part. We as operating men know that a great many

of our problems are worked out at the factory before they are worked out any place else. And, in fact, the history of electrical engineering shows that the factory and the manufacturer have preceded the University and the operator in these matters. I, for one, look with favor upon bringing the manufacturer into the closest possible relation with us as central-station men, since I believe in that way we shall make the greatest progress.

The Power Transmission Section is new. It has been difficult to get into touch with all of the men who are able to do effective work for the Section. There will be occasion to do a great deal of work this coming year. There will be room on the various committees for recognition of the many men who are entitled to recognition and who, it is hoped, will take an active part and interest in the work of the year.

The Chairman: If there is no other business the meeting will stand adjourned.

(Adjourned.)

Technical Sessions

TECHNICAL SESSIONS

FIRST TECHNICAL SESSION—JUNE 11, 2.30 P. M.

1—Report of the Meter Committee. O. J. Bushnell.

2—Paper: Meter Installations. S. D. Sprong.

3—Report of Committee on Grounding Secondaries. W. H. Blood, Jr.

4—Report of Lamp Committee. F. W. Smith.

5—Report of Committee on Electrical Measurements and Values. Dr. A. E. Kennelly.

6—Paper: The Proper Lamp for a Circuit. R. E. Campbell and M. D. Cooper.

SECOND TECHNICAL SESSION—JUNE 12, 10.00 A. M.

1—Report of the Committee on Terminology. W. H. Gardiner, Jr.

2—Paper: New Current Consuming Devices. F. N. Jewett.

3—Paper: Twenty-four Hour Service in Small Central Stations. Taliaferro Milton.

4—Report of Committee on Overhead Line Construction. Farley Osgood.

THIRD TECHNICAL SESSION—JUNE 13, 10.00 A. M.

1—Report of Committee on Prime Movers. I. E. Moultrop.

2—Report of Committee on Electrical Apparatus. L. L. Elden.

3—Report of Committee on Underground Construction. W. L. Abbott.

4—Paper: Care and Operation of Transformers. W. M. McConahey.

FIRST TECHNICAL SESSION

Tuesday Afternoon, June 11

The Chairman, Mr. W. C. L. Eglin: The first paper will be the report of the Committee on Meters, Mr. O. J. Bushnell, Chicago, Chairman.

REPORT OF COMMITTEE ON METERS

The work of your Committee during the past year has been somewhat of a departure from that heretofore carried on. Of the many problems in meter work, the greatest difficulty at the present time, seems to the Committee to lie in the securing of properly trained metermen. The young men who enter upon this work have as a rule little technical education and frequently no electrical experience. After a few years these men are likely to be promoted to other branches of the business, so that it is necessary for a large company to continually educate new men for meter work. The instruction of these men has necessarily been left largely to those with whom they are associated in their work, and as a result has frequently not been as comprehensive or as thorough as was desirable, sometimes resulting in losses to the Central Station Company from the acquisition of knowledge by experience which should have been otherwise available.

The Committee also found in this connection that a very large amount of valuable information on meter work had been accumulated by previous Committees and given out in their reports, but that these reports, individually, are now out of print and can be obtained only in the bound *Proceedings* of the Association, so that they are not available generally to meter men. The Committee accordingly considered that it would perform the greatest service to the member companies of this Association if it should compile a Handbook for metermen which would deal with meter questions in an elementary, practical way, so as to be available for the instruction of new men and yet cover all the technical questions which might arise in the management of a meter department.

ELECTRICAL METERMAN'S HANDBOOK

The Committee, accordingly, set itself to this task and has written and compiled the Electrical Meterman's Handbook, which is now available for the members of this Association. This work could hardly have been accomplished but for the valuable assistance of many others outside the Committee and the ready co-operation of the several manufacturers of meters and meter appliances. This help the Committee gratefully acknowledges, and

more particular mention of it has been made in the preface of the Handbook.

The Committee has endeavored to include in the Handbook all the available information published in the recent reports of our Meter Committee, and particularly has incorporated those parts of the Code for Electricity Meters which have a bearing on the practical operation of a Meter Department. The Committee further has endeavored to fill out the information along those lines where there have been further developments and has written several chapters on subjects which have not heretofore been treated in a report. The Handbook also includes information respecting those types of watt-hour meters which are at the present time in considerable use throughout this country, although no attempt was made to cover every meter that is manufactured. The information given respecting types of meters, while not entirely complete, the Committee believes will prove of great value for reference. Descriptions have been included also of all the different lines of auxiliary apparatus for testing and installing meters, of which the Committee could secure information, with the name of the manufacturer from which it can be secured.

In presenting this Handbook the Committee trusts that you will bear in mind the short time available for its production and will consider it a proof-copy rather than a finished work. If it shall prove in any way to fill the want for which it has been designed, it will be desirable to have it revised and republished within a year or two, and the Committee will be gratified if it shall have blazed the way for the production of such a Handbook as, in its opinion, is greatly needed.

THE CODE FOR ELECTRICITY METERS

The Code for Electricity Meters, formerly called the Meter Code, which has been prepared by the Electrical Testing Laboratories under the instructions of the Joint Meter Committee of the Association of Edison Illuminating Companies and the National Electric Light Association, was completed by our Committee of last year.

According to arrangement, however, part of the Code written during that year was presented at the N. E. L. A. Convention a year ago, and the final section at the convention of The Association of Edison Illuminating Companies last September. In order

to complete the publication of the Code in our *Proceedings* there has been added to this report the final report presented at the Edison Convention, consisting of some additional paragraphs to Section V, concerning Wiring Protective Devices, and Section VI entire, on Installation Methods.

For the purpose of reviewing the specifications of the Code for Electricity Meters and to insure their being generally acceptable to the public authorities, the national associations and the meter manufacturers, a joint meeting and conference, under the auspices of the Meter Committee of the Association of Edison Illuminating Companies and this Committee, was held in February, at which were present members of the two Committees, representatives of the meter manufacturers, and also representatives of the Public Service Commissions of the four States which have undertaken the supervision of electricity meters. The Specifications of the Code were reviewed and adopted with only slight modifications. The matter was then left in the hands of an editing committee, representing the Electrical Testing Laboratories and the two Meter Committees, to prepare the Code for final publication, and it will soon be made available in complete form.

While much of the material of the Code which treats of the operation of meters has been incorporated in the Handbook, it must not be supposed that the former has in any way been superseded. The Code alone contains the prescribed methods of acceptance tests and the full specifications for the acceptance of meter types and types of auxiliary devices, the standardization of which is proving extremely valuable. The final approval of these Specifications on the part of this Association will be requested upon the publication of the Code for Electricity Meters in revised form.

TYPES OF WATT-HOUR METERS

The new types of cheaper induction meters which were described in detail in last year's report of the Committee, have been used to a large extent by member companies during the past year, and, as far as your Committee has been able to ascertain, with very satisfactory results. There have been further developments in the manufacture of meters during the year, although not as extensive as during the previous year.

The Westinghouse Company has changed the design of its continuous current, watt-hour meter, making it practically identical with that of the Thomson watt-hour meter. The Duncan Electric Manufacturing Company has brought out an induction meter and has also redesigned some types of their continuous-current meters. Descriptions of these new meters can be found in the Handbook, and, accordingly, mention, only, is made of them here.

MAXIMUM LOAD INDICATORS

The Chicago Electric Meter Company has brought out two new types of maximum load indicators, called respectively the maxicator and the maxometer, embodying the fundamental principles of the Merz patents. Full descriptions of both can be found in the Handbook.

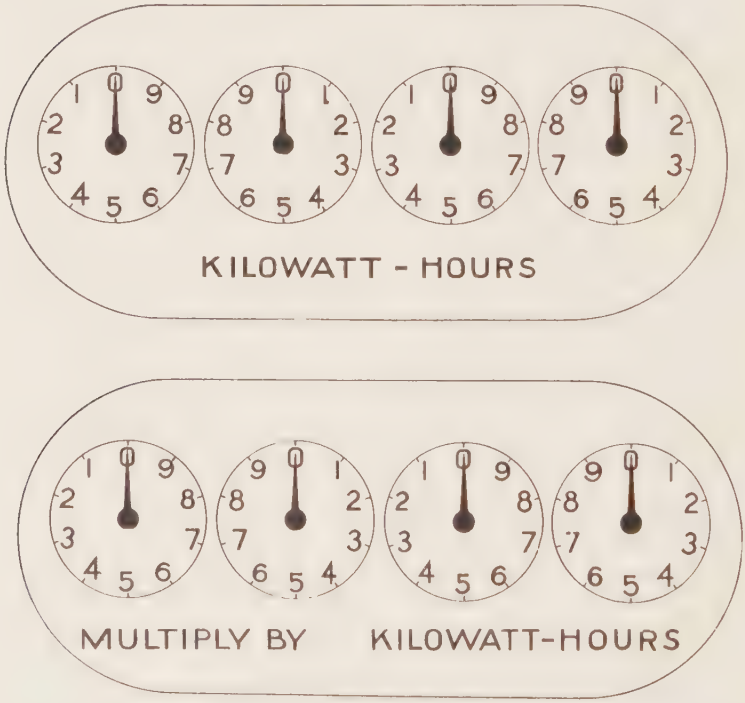
An interesting report has been made this year by the Board of Gas and Electric Light Commissioners of Massachusetts, pursuant to a resolution that they investigate the operation of demand indicators and determine whether or not it is expedient to regulate, or prohibit, the use of such meters. The construction of demand indicators was very thoroughly reported on and in their conclusion the Board, while expressly stipulating that it did not sanction differential or discriminating prices for electricity, recognized the commercial necessity, in the present development of the industry, of making prices for large or long-hour users of electricity sufficiently low to attract the business. With respect to demand indicators, the report says: "The examination of demand indicators made by the Board has convinced it that, if properly constructed and calibrated, and properly handled and inspected by the companies' employees while in use upon the customers' premises, they may be expected to operate correctly within certain reasonable limits."

METER CONNECTION AND PROTECTIVE DEVICES

New developments in the line of these devices have been brought out during the year by the Metropolitan Engineering Company and the Appleton Electric Company, for descriptions of which you are again referred to the Handbook.

STANDARDIZATION OF METER DESIGN

The Committee has given attention during the year to the standardization of meter design and has secured the consent of several manufacturers to the adoption of a standard form of marking for watt-hour meter dial faces upon its being recommended jointly by the Meter Committee of this Association and that of the Association of Edison Illuminating Companies. Details of this design which embody doing away with the marking of any value over the individual dials and with all lettering on the dial face except KILOWATT-HOURS and a constant of decimal ratio when necessary, are now being worked out between the two Committees.



PROPOSED STANDARD MARKING FOR WATT-HOUR METER DIAL FACES.

The standardization of meter terminals has also received attention, and while this is a matter on which the opinions of men in different companies vary greatly, this Committee has gone

on record with the manufacturers, as favoring meters with bottom terminals. The same stand has been taken by previous committees and had weight in the design of the later types of meters. The Committee believes that the manufacturers will be glad to come to a uniform practise in this regard if the requirements of Central Station Companies can be made uniform. At present some manufacturers, to satisfy different companies, make meters with either top, or bottom, connections. This necessarily tends to increase the cost of manufacture, and consequently the selling price, so that it would utimately be to the advantage of the companies if they could unite on the recommendation of the Committee.

AMPERE-HOUR METERS

Your Committee recognizes that in elaborating and standardizing meter practise, there is a danger that questions of meter accuracy will be viewed from a technical and laboratory point of view rather than from a practical one. With the decrease in the cost of electricity and the increased efficiency of electric lamps, the number of small consumers supplied by our Central Stations is constantly increasing. It will be conceded that it would be a public benefit to have the use of electricity brought within the reach of just as many as possible. To make this possible, these small consumers must be charged on an equitable basis which shall also be profitable to the Central Station. As illustrating the extent to which this small business is growing, it may be stated that two-thirds of the customers of one of our largest companies are supplied with current through watt-hour meters with a rated capacity of only one-half kilowatt, and that this same company has 12,000 customers whose bills during the whole year average less than $1.00 per month. When the meter maintenance, including interest on meter investment and depreciation, together with the expense of reading the meters and rendering the bills, amounts to 25 cents per month, as has been conservatively estimated, there can be little profit in the current supplied to such small consumers. It is on this account, that many Central Station Companies charge a minimum monthly bill, and while this may become necessary for all, the practise is without question a hindrance to the use of electricity by these small consumers.

Under these circumstances, it would seem that a meter

cheaper than the ones now in use, especially for continuous current, is an absolute necessity. Apparently, the hope of such a continuous current meter must be based on an ampere-hour meter rather than the watt-hour meter. The objection to the use of an ampere-hour meter rests entirely on the fact that it does not take into account the voltage variations of the circuit, and consequently the difference between the voltage for which the meter is calibrated and the service voltage might cause an error additional to any error arising in the meter itself. It is, consequently, necessary to know not only the accuracy of the meter but the average voltage of the circuit on which it is used, to determine the accuracy of the registration.

While the voltage regulation in some companies is doubtless so good as to permit of the use of an ampere-hour meter without its accuracy of registration falling outside the limits now prescribed in States where this matter is regulated, in many companies there are likely to be parts of the system where the voltage at times varies above or below the usual limits prescribed for meter accuracy.

In a decision of the Wisconsin Commission made during the past year with reference to the use of ampere-hour meters, their use was permitted, but rather burdensome regulations were placed upon the Central Station Companies for determining the voltage in the different parts of the system at intervals of three months, and of correcting the consumption registered by the meters on a basis of the variation of the voltage from standard. If the use of ampere-hour meters were limited to capacities not exceeding ten amperes and perhaps to installations on which the consumption would not exceed a fixed amount, it would seem that the State Commissions might well consider the advisability of allowing wider limits of accuracy, if necessary, to permit the use of such a meter, or that they might sanction its use by companies whose usual voltage variation had been demonstrated to be within proper limits, without considering the slight voltage error which might arise in some cases. Such action would be a benefit, not so much to the Central Station, as to the people at large, inasmuch as it would enable the Central Station Companies to supply service to small consumers whom they cannot afford to take at the present time. Considering also the small amount of

money involved in the bills, the use of such a meter under restrictions would not work any injustice to the consumer.

While your Committee does not believe in any lessening of effort to obtain the greatest possible accuracy in connection with meter work in general, it does recommend such concessions in the regulations as applied to very small consumers, as will make the advantages of electricity available to them through the general use of a cheap ampere-hour meter.

Committee { O. J. Bushnell, *Chairman*
F. A. Vaughn, *Secretary*
W. E. McCoy
W. H. Fellows
W. L. Wadsworth

CODE FOR ELECTRICITY METERS

SECTION V

(Continued from Proceedings of 1911.)

H—Wiring Protective Devices—Specifications for Design and Construction

32. The device, in conjunction with the service conduit, must effectually enclose and seal all circuits on the service side of the meter.

33. The device must be easily adapted to the various types of meters used and to the various conduit locations necessary in practise.

34. The wires should enter and leave the device with a minimum of crossing.

35. Facilities should be provided for easily and safely making connections for test without interrupting the consumer's circuit. When connected for testing, the consumer's circuit and the testing circuit should both be fused.

36. The device must be so designed and constructed as to have no effect on the accuracy of the meter. (See tests in Clauses 40, 41 and 42.)

37. The material and workmanship must be first-class.

I.—Wiring Protective Devices—Acceptance Tests

38. Devices which comply with the specifications for design and construction given above shall, for acceptance, be subjected to the following tests.

39. All tests shall be repeated, using each type of meter with which the device will be used.

Test No. 1—Difference Between Testing and Service Conditions

40. The device shall be set up as used in service, and the accuracy of the meter shall be determined at 10 per cent load and at 100 per cent load, introducing the standards by means of the testing connections. This test shall be made under two conditions, namely, (a) with no load in the line circuit and (b) with full load (corresponding to a consumer's load shunted past the meter) in the line circuit. No difference in accuracy at the same load, not attributable to variation in the meter itself, shall be permissible. The accuracy of the meter shall then be deter-

mined at 100 per cent load, using the normal service connections and introducing the standards in series with the line. The accuracy thus found shall be the same, within the variation of the meter itself, as that found with the standards connected to the special testing connections.

Test No. II—Continuous Current Meters

41. The meter shall be installed in the device in the same manner as in service. A current of 400 per cent of the rated value shall then be passed through the meter in the reversed and also in the normal direction. In neither case shall any appreciable permanent change in the magnetic condition at the center of the armature be produced.

Test No. III—Alternating Current

42. An alternating-current meter of each type to be used with the device shall be tested at 10 per cent and at 100 per cent load before and after installing in the device. No difference at the same load not attributable to variation in the meter itself, shall be permissible.

SECTION VI—INSTALLATION METHODS

A—Locations

1. The question of meter location should be carefully considered in the first stages of laying out the installation. Not only for the sake of accuracy but for convenience in reading and testing, it is to the interest of both the consumer and the company that a suitable location be provided.

2. In new buildings, especially in the case of large office buildings and apartment houses, special meter closets of ample size should be provided in the halls or the basement from which separate circuits run to the different suites. The company should keep the architects and contractors informed as to the requirements, and the provision for installing the meters must be such as to meet the approval of the company's representative, especially in regard to facilities for testing. In old buildings it often occurs that an ideal location cannot be obtained, and a compromise must be made by choosing the location with the fewest undesirable features.

3. Meters must be installed in the nearest suitable location to the point where the service enters the building. The circuit

should be enclosed in continuous iron conduit from the service to the meter. The requirements of the meter should, therefore, be considered in locating the service and the inspector who determines the location of the service should either have sufficient knowledge of the meter to know what to avoid or should work under rules which are adequate to insure the proper results. The requirements of a suitable meter location are given in the following clauses.

4. The meter should be accessible with a minimum of annoyance to the tenants; should be so located that it may be easily read and should have sufficient space around it so that the tester has no difficulty in arranging and using his apparatus or in inspecting and adjusting the meter.

5. The meter should be installed not more than 7 feet from the floor, on a stable support, in a clean, dry, safe place, free from vibration and magnetic disturbances. Among undesirable locations may be mentioned the following:

In Kitchens,
Living Rooms,
Bed Room Closets,
Bath or Toilet Rooms,
Janitor's Hall Closets,
Attics
Damp Cellars,
In Coal Bins
Elevator or Ventilating Shafts,
Near Stoves or Radiators,
Steam or Gas Piping,
Electric Machinery,
Over Doors or Windows.

6. When a number of meters are installed together, the distance between centers should be not less than 15 inches.

B—Choice of Meter

7. The meter assigned to each installation should be suited to the voltage, frequency and character of the circuit and should be chosen with a view to obtaining the best adaptation to the local conditions and to the load. It is not advisable to use commutator meters on alternating-current circuits. Unlagged meters should never be used on inductive loads.

8. Meters are generally most accurate when operating between 25 and 125 per cent of their rated current capacity. The meters for a given installation should be so chosen that the average load comes well within these limits and as near to its rated capacity as is possible without danger of damaging it

or impairing its accuracy. Where the maximum load is of very short duration or occurs only at rare intervals, the preference should be toward smaller capacity meters. If, however, the duration of the light load is short compared with that of the heavy load, the meter should be chosen to give the best accuracy under the latter condition.

9. The connected load is generally taken as the sum of the ratings of all the apparatus connected to the circuit. The percentage of the connected load which is in use at any one time is dependent upon the character of the installation and the business of the consumer, and it is at this point that the greatest uncertainty is encountered in choosing the proper size of meter. In large installations the question may be settled by a study of individual cases, but for small installations it is necessary to adopt general rules for various classes of consumers.

10. In residences and apartments meters rated at from 35 to 50 per cent of the connected load should generally be used. Ordinary stores require meters rated at about 75 per cent of the connected load, but large wholesale houses, where the lights are in use only when exhibiting goods, should be treated similarly to residences. It is not, however, customary to use meters of lower than five amperes rating.

11. Where the load is practically constant, such as restaurants, saloons, stores where all of the lamps are used at one time, signs without flashers and moving picture arcs (when metered separately from the auditorium lights), the capacity of the meter should be approximately equal to the connected load.

12. For single motors the meter capacity is usually equal to the current rating of the motor. When several motors are connected through the same meter, the diversity factor of the load often is such that a meter rated at much less than the combined ampere capacities of the motors may be used.

13. In large installations it may sometimes be advantageous to subdivide the load, metering the various divisions independently. Small loads of long duration should be metered separately from large loads of short duration. Two or more loads whose maximum values are equal but occur at different times may advantageously be combined on one meter. Two or more loads of unequal value may also be combined, provided that the smaller

load is never used without the larger. In some cases, however, on account of the diversity factor of the installation, the average percentage of full load at which the meters operate will be reduced rather than increased by subdividing the installation, in which case a single meter should be used.

14. In churches, theatres, department stores, factories, etc., separate meters may advantageously be installed for the large number of lights used occasionally and the smaller number used for cleaning, etc.

15. Aside from the question of accuracy of metering, the subdivision of the installation has the advantages that the consequences of failure or error in a single meter are lessened, less special equipment for testing is needed, and reasons for fluctuations in the bills are more easily determined. Its disadvantages are that the investment and the labor of testing, reading and billing are, on the whole, increased, and that on account of the diversity factor of the installation, the smaller meters must have a greater aggregate capacity than would be required in a single meter for the whole installation.

16. In very large installations which are metered as a single circuit, it is sometimes found advantageous to connect several meters in parallel, instead of using a single meter of large capacity. Especial pains must be taken to insure equal resistances in the various current circuits to prevent overloading any of the meters.

C—Wiring

17. This section deals only with those aspects of wiring necessary to satisfactory metering and, therefore, no regulations as to allowable drop, balancing of three-wire circuits, grounding, etc., are included, nor do the regulations of this section duplicate or conflict with the Electric Code of the National Board of Fire Underwriters.

18. The company has the right to inspect all circuits and apparatus at any time to insure that they are properly metered.

19. Each meter should be protected by its own sealed cut-out, placed between the meter and the point where the service enters the building.

20. No meter should be so connected as to include the registration of another meter, except for purposes of special investigation or where required by special conditions.

21. Where several meters are grouped together, the circuit in which each one is connected should be plainly indicated, and all circuits should be carefully traced to insure that there is no error in the wiring whereby one consumer obtains current through another consumer's meter. This is especially important where the wiring is concealed, in which case the service and load wires should be tagged.

22. Open wiring, where used, should be arranged with a view to minimizing the likelihood of incorrect or improper connections. The wiring around the meter should be arranged neatly, without unnecessary crossing, and in such a manner as to minimize the liability to confusion between the different circuits.

23. Both sides of a two-wire circuit should, where practicable, be carried through the meter. When this is done, the meter should be tested with the return bar in circuit (See VII, Figs. 11 to 19), unless comparative tests with and without the return circuit show the given type and capacity of meter to be unaffected.

24. In two and three-wire circuits where a separate potential tap is used precaution should be taken to prevent its becoming disconnected. The connecting wire should be as short as possible, should be accessible for inspection, and should be soldered to the return or neutral circuit. Where several branch circuits are supplied through the same meter, the potential tap should be carried back to the main line. Otherwise, it may become disconnected by the opening of the fuse in one of the branch circuits.

25. In wiring three-wire meters, care should be taken that both the current coils are connected in the outside wires and that they are not connected in opposition.

26. In wiring polyphase meters, especially when used with voltage and current transformers, great care is necessary to obtain the right connections. The meters should be wired in exact accordance and with the manufacturer's diagram, and in addition the connections should be tested out to insure that the meter operates correctly. (Clause 35.)

27. The wiremen should leave a free end at least 18 inches

long on each circuit to give ample wire for connection to the meter.

28. Where no meter terminal box is used the conduit for the service wiring and the conduit or molding for the house wiring must terminate at a sufficient distance (6 inches or more) from the meter to permit easily changing the connections for testing purposes.

29. Where meters are installed in closets or compartments, the conduit or molding should terminate in plain view within the compartment. In a 3-wire circuit the neutral, and in a 2-wire circuit the grounded side of the circuit, should pass through the compartment.

D—Installation Devices

30. Where open wiring is used it is preferable to mount the meter and the service cut-out on a suitable meter board of standard size, which is securely fastened to the wall. On bricks, concrete, terra cotta or metal walls, the boards must be set out from the wall, leaving an air space of at least ⅞ of an inch back of the board.

31. It is good practise in many instances to employ meter installation devices which, together with the continuous conduit (Clause 3) and the sealed service cut-out enclose and seal all the wiring around the meter. Complete protection is thus provided for all unmetered parts of the circuit. Specifications for the acceptance of such devices are given in Section V, Clauses 32 to 42.

32. Generally, a standard form of box is employed with metallic trim for fitting it to the various types of meter. In some cases, the service cut-out is incorporated in the device.

33. By a proper design of the installation device, the ease and accuracy of testing may be increased.

34. In the case of induction coils, wireless telegraph apparatus, high-potential testing transformers, etc., where the high voltages or high frequencies produced are likely to injure the meter or to interfere with accurate registration, the consumer should install an approved device capable of protecting the company's apparatus from the injurious disturbances. The form of apparatus required will differ under different conditions, and should be designed in consultation with, and with the approval of, the company's engineers.

E—Methods for Verifying Connections

CONTINUOUS CURRENT AND SINGLE-PHASE CIRCUITS

35. The main use of these methods for verifying or "testing out" the connections is in cases where the circuits are concealed, but tests are also advantageous even when the wiring may be traced as in many cases it is difficult to follow the circuit throughout its entire length.

36. To determine whether a circuit is alive or not, connect to it an incandescent lamp or voltmeter. Where there is any danger of the circuit having become crossed with a high-tension line, a number of lamps sufficient to withstand the maximum voltage likely to be found should be connected in series and short-circuited one by one.

37. The polarity of a continuous current circuit may be determined by means of a continuous current voltmeter. Special polarity indicators are also available. Where no other means is at hand, two copper wires may be dipped into a strong solution of common salt, a lamp being connected in series to limit the current. For weak currents, a faint green color will appear near the positive terminal; for stronger currents a pronounced brownish-yellow color will appear at the negative terminal.

38. To determine which side of a circuit is grounded, connect a lamp or voltmeter from each side to an active water-pipe or other grounded object. The lamp will light up on the ungrounded side, but will not light up on the grounded side. If the circuit has no connection to the ground, the lamp will not light up on either side of the circuit.

39. To determine if all the apparatus in a given installation is connected to the meter, open the circuit at the meter and try turning on each piece of apparatus in turn. If any lamp lights or apparatus operates it indicates that it is connected to the service side of the meter or to another circuit, or that the meter is shunted.

If the current coil has by mistake been connected in the grounded side of the circuit and there is a ground in the consumer's lines as well as in the service mains, the ground acts as a shunt around the meter. (See Section III, Clause 18.)

If turning on all the apparatus would overload the meter

or transformer, the test should be made on a part of the installation at a time.

40. If when all consumer's apparatus is turned off, a spark is obtained on disconnecting the load wire from the meter, it indicates leakage in the consumer's lines or other hidden cause of energy consumption. A lamp burning in an out-of-the-way place may often cause a consumer to complain about the registration of the meter. Where the consumer's wiring can be separated into sections by taking out fuses at the branch cut-outs, testing each branch separately will greatly assist in locating the hidden load.

THREE-WIRE CIRCUITS

41. If the neutral circuit is open, a voltage may be obtained from neutral to ground, the value of which will depend on how much the consumer's load is out of balance.

42. Where no voltage is obtained between the outer wires but normal voltage is obtained between each outer wire and the neutral, it indicates either that the circuit has been connected

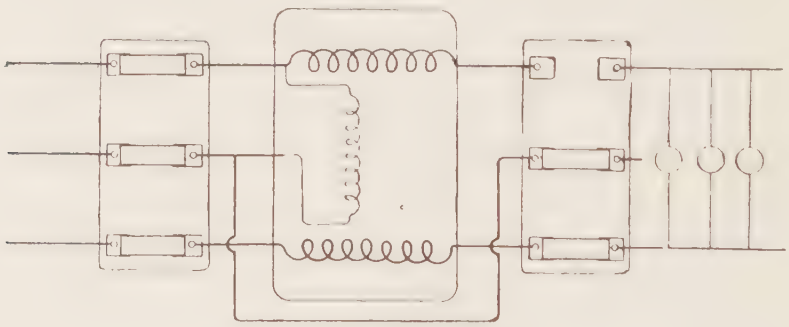


FIG. 1

two wire or that one of the outer wires is open and that most of the load is connected between the outer wires as shown in Figure 1.

THREE-PHASE CIRCUITS

43. The following method has been suggested and found useful for determining the correct connections of a polyphase meter in a three-phase circuit.

44. The meter should be so connected that when the power-factor is less than 100 per cent and over 50 per cent, the meter

will rotate forward with either element cut out, but the speed will be less with one element than with the other. When the power-factor is less than 50 per cent and more than zero, rotation will be forward with one element cut out and backward at a lower speed with the other element cut out. The resultant rotation will, however, be forward.

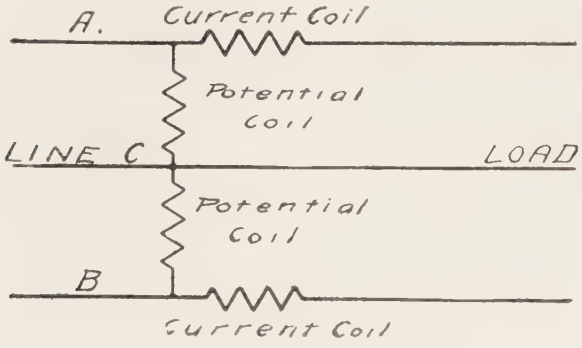


Fig. 2-A—Without Voltage or Current-Transformers

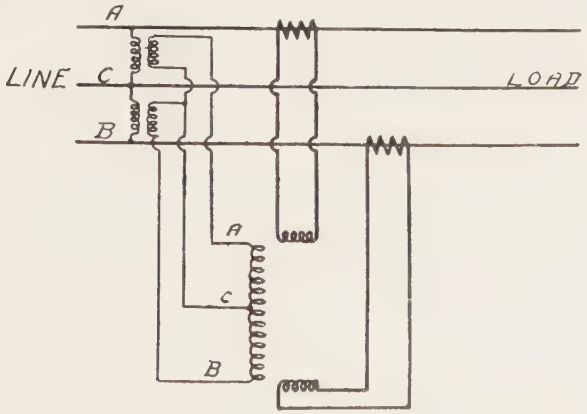


Fig. 2-B—With Voltage and Current-Transformers

45. In cases where it is not positively known that the power-factor is above 50 per cent, the following method may be used:

First: By testing with an incandescent lamp or a voltmeter; see that the voltage leads A, B and C have equal voltages between them.

Second: Connect these leads to the voltage circuits of the meter as shown in Figure 2.

Third: Connect the current transformer in line A to the element whose potential coil is connected to AC and the current transformer of line B to the element whose voltage circuit is connected to BC. Figure 4 is a vector diagram showing the phase relations with these connections. In this diagram AC represents the voltage on the element connected at A, BC the voltage on element connected at B, CA the current in the element connected at A, and OB the current in the element connected at B.

Fourth: Disconnect the current coil B, and note the speed of the meter with element A alone. Then change the voltage connection of element A from AC to AB as shown in Figure 3. If the power-factor is 100 per cent, the meter will run at the

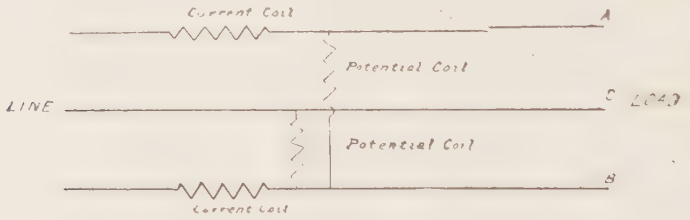


FIG. 3

same speed as before. If the power-factor is less than 100 per cent and greater than 50 per cent, the speed of the meter will be different, but will be in the same direction in each case. If the power-factor is less than 50 per cent, the meter will run in opposite directions with the two connections.

Fifth: The same test may be performed on element B by changing the connections of its voltage coil from BC to BA.

Sixth: If it is found from the above tests that the power-factor is greater than 50 per cent, connect the current coils so that each element tends to run forward. If the power-factor is less than 50 per cent, connect the current coil of the slower element so that it tends to run backward and the current coil of the faster element so that it tends to run forward.

NOTE.—If the changes are made while the circuits are alive, care should be taken to never open the secondary circuit of a current-transformer. Serious injury might result or the magnetic state of the iron

might be altered sufficiently to materially change the ratio. These dangers may be avoided by always short-circuiting the transformer secondary before opening the meter circuit.

46. Where the connections cannot be easily traced, ringing out by the ordinary magneto method, is the most reliable means of identifying the various circuits.

F—Rules and Precautions for Meter Installation Work

47. In the following clauses the aim is to give the main points which should be looked after in connection with the installation of the meter. In small companies the installation work is generally done by the meter men, who are therefore

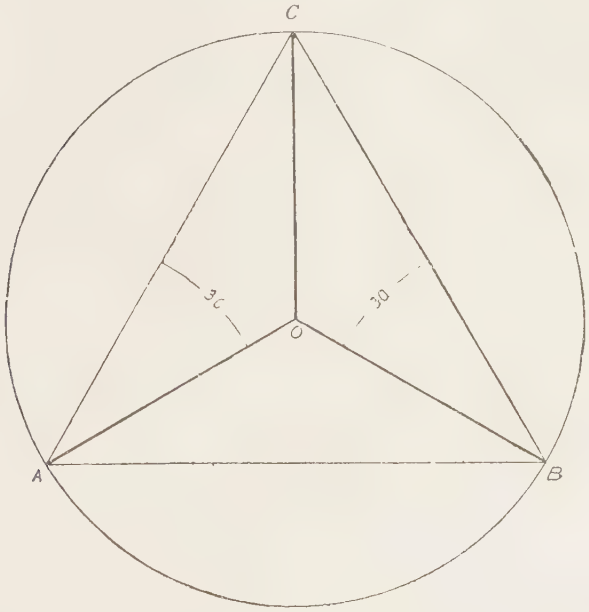


Fig. 4

capable of attending to all of the points mentioned. In large companies it is the custom to have the meters installed by a set of men who are not testers and whose knowledge of meters is very limited. In such cases the installation work is checked up by an installation inspector who has been trained in the meter department, and who looks after such points as are beyond the province of the installer.

48. Before connecting a meter be sure that it is of the proper type and has the right voltage, frequency and current-rating for the circuit.

49. Between the time of the laboratory test and the installation of the meter it should be handled carefully and not subjected to jars or severe vibration.

50. In attaching a meter to a wooden support, start the screws by means of a small hole made with an awl. Do not use a hammer. Any hammering which must be done on the board should be done before the meter is set up.

51. The installer should be thoroughly familiar with the connections of all the meters used as given in the manufacturer's catalogues or special instructions.

52. The installer or inspector should look the meter over to insure that it has not been damaged in transportation.

53. See that all connections are firmly held under the proper binding posts.

54. Connect sufficient load on the load side of the meter to see that it rotates in the proper direction. If the rotation is incorrect, there has been some error in the connections. Probably the service and load wires are interchanged.

55. Test to make sure that the current coil is not in the grounded side of the circuit (see Clause 38).

56. Make tests to insure that there is no electrical connection between any circuit and the frame (see Section IX, Clause 67).

57. Special care should be exercised to see that no dirt falls into the meter.

58. Seal both the cover and the independent terminal compartment, if any.

59. Before leaving the meter, see that it responds freely under load. This, where practicable, should be done after replacing the cover.

60. All record forms should be carefully and accurately filled in.

MR. BUSHNELL (continuing): The committee has prepared, in addition to the report just submitted, an exhibit of its Committee on Meters, which will be found in section 13 of the main hall, where we have grouped together for general information

all the present American types of watt-hour meters, some of the best grades of instruments, including primary standard instruments, secondary standard and transfer instruments and working standard instruments, and also auxiliary devices for testing meters, such as load boxes, rheostats, transformers and various tools and appliances. There will be some one in charge to explain these devices, if you find anything there of especial interest.

In addition to this the main work of the committee this year is shown in the Electrical Meterman's Handbook, to which reference is made in the report.

It is, of course, impossible to give you any résumé of what is contained in this book, as it has nearly eleven hundred pages, but, if I am not trespassing too much on the time of the meeting, I will ask permission of the chairman to read to you the preface of the Handbook, which will give you some idea of its scope.

(The speaker thereupon read the preface.)

EXHIBIT OF THE COMMITTEE ON METERS

The exhibit of the Committee on Meters, at the Seattle Convention, was intended, in general, to illustrate all the present types of American meters and, so far as possible, the instruments and appliances for meter work which are available and are described in the Electrical Meterman's Handbook. The exhibit was somewhat restricted, both by the amount of space available and the location of the Convention so far from the members of the Committee that it was necessary to ship most of the apparatus from a distance and considerably in advance of the Convention.

Exhibit of the Meter Committee

The booth was adjacent to one of the entrances to the main Convention hall and was visited by a large number of people, who manifested considerable interest in the display. The exhibit was installed by Mr. A. G. Turnbull, of the Commonwealth Edison Company, of Chicago, who, together with Mr. W. L. Wadsworth, of the Committee, acted as demonstrator during the Convention. Valuable assistance in placing the exhibit was also given by Mr. R. E. Thatcher, of the Seattle Company, and his assistants.

The material for the exhibit was largely contributed by the manufacturers of the meters, instruments and devices shown. In addition, exhibits were received from the Edison Electric Illuminating Company of Boston, the Philadelphia Electric Company, the Puget Sound Traction, Light and Power Company, the City Plant of Seattle and the Commonwealth Edison Company of Chicago. The Committee gratefully acknowledges the assistance of all the manufacturers and the companies who so kindly co-operated with it to make the exhibit successful. The apparatus exhibited was, in general, grouped according to class, rather than manufacture, and consisted of the following:

Continuous-Current Watt-Hour Meters.

Columbia type D watt-hour meter, capacity 5 amperes, 220 volts.
Duncan model E watt-hour meter, capacity 5 amperes, 110 volts.
Sangamo type D watt-hour meter, capacity 10 amperes, 110 volts.
Thomson type C-6 watt-hour meter, capacity 50 amperes, 230 volts.
Westinghouse type CW-6 watt-hour meter, capacity 10 amperes, 110 volts.
Willis straight-line watt-hour meter, capacity 5 amperes, 110 volts.

Astatic Continuous-Current Watt-Hour Meters.

Duncan model EA watt-hour meter, capacity 25 amperes, 110 volts.
Duncan model ER multipolar shunted type watt-hour meter, capacity 600 amperes, 110 volts.
Thomson type CQ multipolar watt-hour meter, capacity 50 amperes, 220 volts, 3-wire.

Single-Phase Alternating-Current Watt-Hour Meters.

Columbia type C induction watt-hour meter, capacity 5 amperes, 110 volts.
Duncan model M induction watt-hour meter, capacity 5 amperes, 110 volts.
Fort Wayne type K-3 induction watt-hour meter, capacity 5 amperes, 110 volts.
Fort Wayne type K-4 induction watt-hour meter, capacity 5 amperes, 110 volts.
General Electric type I induction watt-hour meter, capacity 5 amperes, 110 volts.
General Electric type I-10 induction watt-hour meter, capacity 5 amperes, 110 volts.
Sangamo type F mercury watt-hour meter, capacity 10 amperes, 110 volts.
Sangamo type H induction watt-hour meter, capacity 5 amperes, 110 volts.
Sangamo type H induction watt-hour meter, with glass case, capacity 40 amperes, 110 volts.
Westinghouse type C induction watt-hour meter, capacity 5 amperes, 110 volts.
Westinghouse type OA induction watt-hour meter, capacity 5 amperes, 110 volts.

Polyphase Alternating-Current Watt-Hour Meters.

General Electric type D-3 induction watt-hour meter, capacity 5 amperes, 230 volts, 3-wire, 3-phase.

Westinghouse type C induction watt-hour meter, capacity 5 amperes, 230 volts, 3-wire, 3-phase, connected with 3 current transformers, for use on a 4-wire, 3-phase circuit.

Prepayment Watt-Hour Meters.

Thomson type CP-4 continuous-current prepayment watt-hour meter, capacity 5 amperes, 115 volts, for use with quarters.

Fort Wayne type K-3 alternating-current induction prepayment watt-hour meter, capacity 5 amperes, 110 volts, for use with quarters.

Westinghouse type B, alternating-current, induction prepayment watt-hour meter, capacity 5 amperes, 110 volts, for use with quarters.

Continuous-Current, Ampere-Hour Meters.

Sangamo mercury automobile type E ampere-hour meter, capacity 40 amperes.

Sangamo distant dial mechanism for automobile type E ampere-hour meter.

Reason electrolytic ampere-hour meter, calibrated to read in kilowatt-hours, capacity 10 amperes.

Chamberlain and Hookham mercury ampere-hour meter, capacity 5 amperes.

Maximum Demand Indicators.

Wright demand indicator and shunt for continuous-current, capacity 800 amperes.

General Electric type W alternating-current watt-demand indicator, capacity 5 amperes, 110 volts, 3-wire, 3-phase.

Maxicator and contact making motor, Chicago Electric Meter Company, attached to General Electric Type I alternating-current, induction watt-hour meter, capacity 5 amperes, 115 volts.

Printometer, type SC, and contact-making clock, Chicago Electric Meter Co., attached to Fort Wayne type K-3 polyphase induction watt-hour meter, capacity 5 amperes, 230 volts, 3-wire, 3-phase.

Printometer, type PL and clock, mounted in portable case, Chicago Electric Meter Company.

Meter Testing and Protective Devices.

Metropolitan Engineering Company's Devices, consisting of service and meter testing cut-outs with protective cabinets and meter trim, were shown as applied to the following meters:

General Electric type I alternating-current, watt-hour meter, capacity 5 amperes, 110 volts.

Westinghouse type C alternating-current, watt-hour meter, capacity 10 amperes, 230 volts, 3-wire.

Westinghouse type OA alternating-current, watt-hour meter, capacity 5 amperes, 110 volts.

Fort Wayne type K-4 watt-hour meter, capacity 5 amperes 110 volts.

Thomson type C-6 continuous-current watt-hour meter, capacity 150 amperes, 230 volts, 3-wire.

Laboratory Standards and Instruments.

Weston standard cell.
Leeds and Northrup potentiometer, with 150-volt volt-box, D'Arsonval type galvanometer and 15-ampere standard shunt.
Leeds and Northrup 1-ohm resistance standard.
Leeds and Northrup Wheatstone bridge.
Weston laboratory standard voltmeter.
Weston laboratory standard mili-volt meter, for use with current shunts.
Westinghouse precision ammeter, capacity 5 amperes.
Westinghouse precision voltmeter, capacity 150 volts.
Westinghouse precision wattmeter, capacity 200 amperes.

Working Standard Instruments.

Westinghouse portable alternating-current ammeter, capacity 5 amperes.
Westinghouse portable alternating-current voltmeter, capacity 150 and 300 volts.
Westinghouse portable power-factor meter.
Westinghouse portable frequency meter.
Westinghouse portable current transformer.
General Electric, type P-4, portable alternating-current ammeter, capacity 10 amperes.
General Electric, type P-3, portable alternating-current voltmeter, capacity 150 and 300 volts.
General Electric, type P-4, portable alternating-current wattmeter, capacity 5 amperes, 150 and 300 volts.
General Electric portable split-ring current transformer, ratios 10, 20 and 40 to 1.
Weston portable wattmeter, capacity 10 amperes, 150 volts.
Duncan, model H, continuous-current rotating standard, capacity 1 to 50 amperes, 115 volts.
Duncan, model HA, continuous-current, rotating standard capacity 2½, 5, 10, 20 amperes, 115 volts.
Fort Wayne single-phase, rotating standard, capacity 1, 5, 10, 20 amperes, 115 and 230 volts, equipped with Philadelphia Electric head phone.
Westinghouse polyphase rotating standard, capacity 5, 10, 20, 40 amperes, 230 volts.

Meter-Testing Rheostats and Load Boxes.

General Electric meter-testing rheostats, capacities 1 to 15 and 1 to 30 amperes, 115 volts.
Ward Leonard meter-testing rheostats, capacities 1 to 5 and 1 to 15 amperes, 115 volts.
Ward Leonard double voltage meter-testing rheostat, capacity 24 amperes at 115 volts and 12 amperes at 230 volts.
Cutler Hammer meter-testing rheostats, capacities 1 to 20 and 1 to 50 amperes, 115 volts.
Philadelphia Electric meter-testing rheostat with tool box, capacity 2100 watts.
Edison Electric Illuminating Company of Boston, calibrated resistance, capacity 1000 watts.
Commonwealth Edison portable water rheostat, capacity 150 amperes at 115 volts.
The States Company type A phantom load, low voltage transformer, capacity 100 amperes.
The States Company potential phase shifter.

Eastern Specialty Company, type H, low voltage transformer load box, capacity 50 amperes.

Edison type B storage battery and carbon rheostat, capacity 75 amperes.

Testing table and panel for small capacity alternating-current watt-hour meters, equipped with 15 ampere General Electric meter testing rheostat and Fort Wayne rotating standard, set flush with top of table.

General Electric torque balance, mounted with Westinghouse type C watt-hour meter and connected up with Weston watt-meter, so as to demonstrate the method of making torque measurements.

Zeuss binocular microscope for examining jewels and pivots, mounted with special reflecting lamp.

Stop watches.

Agassiz chronograph.
Wm. E. Lurch special chronograph.
Geneva chronograph.

Slide rule and leather case.

Repair equipment.

General Electric meter repair kit.
Westinghouse Electric and Mfg. Co. meter repair kit.
Leather tool case.
General Electric meter sealing tool and seals.
Equipment of tools for meter tester, including:

Screwdrivers	Magnifying glass
Pliers	Level
Off-set screwdriver	Wrenches
Brush	Small file
Air syringe	Brush straightener
Needles	Extra dial hands, wing nuts, etc.
Watch oil	Flash lamp
Crocus cloth	Extension lamps
Linen tape	Current leads
Orange stick	Pressure leads
Corn pith	Jumpers
Extra jewels, pivots, shafts and balls	Connectors
	Sealing tool
Box of jewels	Seals

Book of forms used in the Meter Department of the Philadelphia Electric Company.

Album showing pictures of the errometer, for checking the accuracy of meter testing, devised and used by the Philadelphia Electric Company.

Book of forms used in the Meter Department of the Commonwealth Edison Company.

Meter Reader's Book used by the Edison Electric Illuminating Company of Boston.

Meter Reader's book used by the Commonwealth Edison Company of Chicago.

Copies of the Electrical Meterman's Handbook.

Pamphlets and circulars describing the meters and instruments exhibited, for distribution.

THE CHAIRMAN: The report of the Meter Committee is now open for discussion.

DISCUSSION

MR. S. G. RHODES, New York City: The reference of the committee to ampere-hour meters seems timely, in that it would appear that to this meter we must give consideration if we want to reduce the meter investment for continuous current. We have had the benefit of a lower cost of induction meters for some time, and it is just as necessary to obtain a cheaper meter for our low-capacity continuous-current customers.

The ampere-hour meter has been in use in large numbers in Great Britain, Germany and all the Continental countries. Authorities such as the Boards of Trade in England and on the Continent generally, have approved them in their laboratories and approved them as well for service use, and they are therefore no longer an experiment. The rather uncertain feeling of central stations in this country is, I presume, due to lack of familiarity, as all our experience has been with watt-hour meters. It seems to me that while we have an apparent error with the ampere-hour meter, we must consider that the very excellent design of the meter, its operation and its low cost of maintenance all are in its favor. Further, continuous-current systems are very well regulated in this country, and if we take the summation of the errors of ampere-hour meters and the summation of errors in the other types of meters, it is possible, and I think very probable, that the errors, or rather the accuracy of the meter as a whole will not be so very far off from the accuracy of the watt-hour meter.

In the matter of the Handbook comment is hardly necessary as its value is shown on its face. It appears to me that the men to be benefited most will be the metermen themselves, and further, that the meter practise of the country will be made more uniform by such a work. In the Handbook is gathered together in one chapter for the first time the various types of constants, the principles of all the meters are specified in concrete form and a reference is provided for the man who requires very detailed information about them.

There is a chapter in the book, most excellent in character, on complaint investigations, and it includes a reference to the

State of New York Public Service rules and regulations governing this form of test. It includes also a suggestion that the "three-point" method promulgated by the New York State Commission could be made into a two-point method and serve the same purpose. I agree with that sentiment heartily, but inasmuch as this particular method is specified in detail, it occurs to me that it might be interesting to note the experience of a company operating for over three years with the three-point method.

First, it has been satisfactory to the Commission, also to the consumer and to the company. The convenience of a single figure to represent the efficiency of a meter at all loads is obvious, and a comparison of the results obtained on 100,000 tests by this method during 1911 with the older form of testing might prove of value. They prove at least the accuracy and the utility of the three-point method when it is noted that with these 100,000 tests the percentage of the meters in excess of four per cent at full load and again at light load was within approximately one per cent of the efficiency as derived by the single average accuracy figure made a part of the three-point method.

Mr. J. W. Cowles, Boston: I wish to speak a word of commendation and appreciation of the work of the Meter Committee as set forth in the report, and the Handbook presented to us to-day. The comments upon the various points touched in the report are very timely and well warrant consideration. I would speak particularly, however, of the Meterman's Handbook, which stands, it seems to me, as the masterpiece of the work of the committee during the past year. This Handbook certainly goes a long way toward meeting the needs and requirements of our metermen. Never before have we had amassed within the covers of a single book so much data, both theoretical and practical, as in this book. We are all struggling with the problem of educating our metermen. In some cases this problem has become very serious and with this Handbook we have a means of accomplishing a great deal.

Mr. E. R. Northmore, Los Angeles: I have one question as to the ampere-hour meters—Does the report refer to alternating current as well as to continuous current? That is the idea that I get from the paper.

If we are to go to the ampere-hour meter for alternating current, I think we are going backward instead of forward. We

are all trying to increase our day loads, our load-factor, by every possible method, and if we put ampere-hour meters back again are we not going to discourage the use of small machines, sewing-machine motors and other inductive loads on our lines? If we do not do that, we still have the question of testing the meter to find out whether the customer has an inductive motor on his line. I think if we are recommending them for alternating current we are taking a step backward.

Mr. J. H. Jamieson, Vancouver, B. C.: With reference to ampere-hour meters, I myself would recommend them for continuous current. The practical metermen in the room, men who have followed the work for years, know that we have not at the present time a good continuous-current meter, and that the ampere-hour meter is better than the watt-hour meter.

We have conditions over in Vancouver which probably differ much from what you have in this country, due to the fact that we are growing so rapidly. Builders require meters immediately; we have to ship them in and often do not get the chance to test them. At the same time, when they are put into place for large consumers we are handicapped much more than you are in this country, as we are controlled by the government; that is to say, the meters are tested by the government. When a meter is put out by us, it is installed in the customer's premises and will remain there five years. We have no right to break the seals for any reason, no matter how good. Now you all know what continuous-current meters are. My opinion is that they should be checked or tested every three months. When we tried the continuous-current, ampere-hour meters over a considerable area there, where the voltage cuts a figure and drops quite a little out on the lines, we found we got better service than we did from the watt-hour meters. That is our practical experience.

Mr. Farley Osgood, Newark: Our friend from Vancouver has almost answered the question which I was about to ask, namely: Can the committee tell us the feeling of the utilities commissions in the United States towards the use of ampere-hour meters in place of watt-hour meters? If they are preparing to get out a line of rules, such as the member from Vancouver has mentioned, we can see at once that it is going to be somewhat uncomfortable for a committee to make recommendations. I would like to have information from them if they know how the commissions may be expected to treat this matter.

Mr. Joseph B. Seaman, Philadelphia: The Handbook, as it has been presented to us, is unquestionably an admirable work. I have been in close touch with the committee and with the work these gentlemen have done. They have had a tremendous task in preparing the information in this form and presenting it in so short a time. They have very graciously given credit to many others who have furnished some information, but we must not overlook the valuable contributions they themselves have supplied to the industry as a whole. Naturally the committee may feel that the book needs revision and no doubt any work prepared in such a short time would have slight errors, but it is generally conceded that this work is an admirable foundation. If we are to judge of the size of the building from the size of the foundation, it will certainly be necessary for us to speak of this work not as a handbook but as the Meterman's library.

The point brought out by the committee in reference to standardizing the dials is a very important one. Innumerable mistakes occur from the markings as they exist at present on the various meter dials.

The point in regard to terminals is also of importance. It is unfortunate that some of our companies deem it advisable to use a meter with top terminals while others prefer bottom terminals. If manufacturers and lighting companies would agree and standardize the kind of terminals used, both the cost of manufacturing and the cost of installing would be reduced, and we should have meters uniform in design. Both the lighting companies and the manufacturers should welcome standardization.

In regard to the three-point method, I heartily agree with Mr. Rhodes in what he has said; and yet, inasmuch as practically 95 to 98 per cent of the meters, induction meters we will say, are found within the limits of acceptable accuracy when tested on a two-point method, and have practically a straight line accuracy curve, and since no adjustment can be made on a middle point, it seems to me that we are doing a considerable amount of extra and unnecessary work in including the third point in ordinary periodic testing.

The last point I have in mind is in regard to the distribution of the Handbook. It would be a good company investment to supply each and every meterman with one of these books, and

yet there are a certain number of men who would not get as much out of the book if it were given to them as if they paid two or five dollars for it; therefore a problem is presented here which we need to consider very carefully. We should do all we can within reason for the universal distribution of this admirable work, and as I have said, I certainly trust it will tend to unify meter practise throughout the country.

Mr. Rhodes: I want to thank Mr. Seaman for bringing out the point about the New York State three-point method, and particularly that part in which it is understood to take more time to test a meter. This is an error that most metermen have labored under. The meters are calibrated at two points and in this the law of the meter has been followd. The third point is a normal point taken at a predetermined point between the light-load and the full-load capacity of the meter, depending upon the class of installation. If you stop to think for a moment you will note that the instrument and testing leads are all connected up, and it means but the taking of additional readings at this new normal load without calibration. From actual experience under the older method and an experience of three years under the new method, we find just as many meters are tested. Of course it follows also that the more points of a meter you take on its curve, even if it is a straight line, the better the data obtained from which the performance curve is determined.

Mr. F. G. Vaughen, Schenectady, New York: Compliments have been given the committee on this Meterman's Handbook. I would like to add to the commendation that the committee deserves a great deal of credit. The Meterman's Handbook, a part of the committee work for 1912, is a credit to this Association and is without exception the most valuable publication on meters that has ever been printed. Most of the publications which I have read, issued abroad or in this country, have been nothing more than compilations of information gathered from manufacturers' bulletins. This publication, however, has been prepared by a body of men representing American meter practise, and should be invaluable to operating companies and also to metermen of the United States and other countries. It is a most creditable publication.

In reference to the three-point method which Mr. Rhodes and Mr. Seaman have discussed, I think it is very probable there

are but few present who appreciate what is meant by this method. I am in sympathy with Mr. Rhodes' views and especially in connection with the adjustment of complaints. Practically all central stations have certain statistics based upon the monthly bills of different classes of customers. It is not safe to assume that one consumer is always operating on light load or another on full load. There is bound to be some point between the two extremes. Now certain information was compiled by Mr. Green in his report of a few years ago showing the normal load of different classes of customers. A normal point in the adjustment of complaints seems to be justifiable and should be used in dealing with a dissatisfied customer. While the true law of the meter may show a straight line curve, it is not a proper assumption to make that from 25 per cent to 100 per cent capacity the accuracy is the same as between 5 per cent and 25 per cent. It is hardly fair to assume the customer to be between the 5 and the 25 per cent point, or between the 25 and 100 per cent point, but using the statistics which you can get from your own books in the form of monthly bills, you can readily determine how the customer should be classified, and the normal point, as Mr. Rhodes has brought out, will doubtless be of great assistance in adjusting complaints and be a very fair basis on which to reach an adjustment.

I was very much interested in the remarks of the gentleman from Vancouver in reference to Canadian practise. I have followed this practise for some years and have had the pleasure of meeting in Ottawa the gentlemen who have the matter under their charge. I think that the Vancouver as well as other Canadian companies have suffered from the fact that the government has been permitted, so to speak, to go ahead and establish its own laws without either opposition or assistance from operating companies. That is not our way in the States. When public service commissioners get together for the purpose of formulating a set of specifications to govern meter practise, the central stations immediately offer assistance and present facts with a view to establishing a basis which will be workable. In Canada, I understand, the operating companies took no particular part in the formulation of their governing laws and the hardships with which they now have to contend are due to lack of interest or of co-operation.

The same thing, I am told, exists in England. The Board of Trade specifications are very rigid, and should the Board of Trade attempt to enforce or follow their specifications, as they are followed in the States, there would be very few meters used in England. It seems the meter is taken into the laboratory and approved as to type. The manufacturers are then presented with as many thousand of the Board of Trade tags as they need, and as the meter is prepared for shipment the tag is simply riveted to it and out it goes. The operating companies of the United States are working willingly with the Government, their aim being to have practical laws and to obtain the best possible efficiency from the meter systems.

THE CHAIRMAN: Is there to be any further discussion on the meter report? I would not like to close this discussion without pointing out to you that a new record has been made in the affairs of this Association. This book has been compiled, edited, printed and handed to you within the year. I do not believe any other organization has ever made a report as important as this and covering as large a body of facts. Our thanks are due to the members of the committee, but the point I want principally to make is that the large companies, the men who have been taking an active part in the preparation of this Handbook will, of course, immediately put it into use with their own people. The real value of it will unfold in use, and its largest value will be for the smaller companies. It is for you gentlemen to tell your own particular metermen at home and your neighbors that this book is out and may be purchased for a nominal sum. That is, the book will be sold to the member companies at practically its cost for printing. The details as to this you can easily get from the Secretary's office.

I will ask Mr. Bushnell to close the discussion and answer the questions.

MR. BUSHNELL: The committee certainly appreciates the approval which you have accorded its Handbook, and feels amply repaid, I am sure, for the time spent upon it.

The questions have not been very many. With reference to the subject of ampere-hour meters, I would request the gentleman to read from the report: "Under these circumstances it

would seem that a meter cheaper than the ones now in use, especially for continuous current, is an absolute necessity. Apparently the hope of such a continuous-current meter must be based on an ampere-hour meter rather than the watt-hour meter." The discussion following was intended to apply to the class of continuous-current meters and not to alternating-current meters, although this may not have been entirely clear.

With reference to the question of the attitude of State commissions: This is a matter which was not touched upon to any extent in the report, but I think a very important departure has been made in regard to it in the work of our meter committees this year. At the first meeting of our committee last October we had present, by invitation, a member of the Wisconsin State Commission, and he consulted with the committee in a perfectly frank and open manner.

The Wisconsin commission has so far enacted very few regulations concerning meters. They have simply fixed the limits of accuracy required, and have been trying to educate the companies throughout the State to systematic meter testing to bring their meters within the limit, without as yet fixing any penalties or any absolute prescribed method or period of test. Their attitude seems to be that of looking for information from any reliable source. Their representative expressly stated that any recommendations of our committee or any information which we could give them would have the most careful consideration, and due influence on any action which they should take.

Again in February at the joint meeting of the meter committees of this Association and the Association of Edison Illuminating Companies there were public service commission representatives present from four States, and the fellow feeling and co-operation there manifested on both sides augur well, I believe, for our securing very equitable legislation from any State commission, as long as the present policy is carried out.

Although I cannot state anything definite as to the feeling of the commissions on the particular subject of ampere-hour meters, as these have not as yet been used to any considerable extent in this country, I think perhaps the question is partially answered by what I have said as to the general relations existing between the committee and the commissions.

On the subject of three-point tests which has been discussed here no question was asked and perhaps it is not necessary to say anything at all. The Handbook mentions the one point method of normal-load tests as required for a correction of registration by the rules of Chicago; it mentions the two-point method and also the New York three-point method. The relative advantages of each method have not been discussed. I consider, however, that this question of the determination of a single percentage of meter accuracy is one of the most important questions yet to be decided. The previous meter committee did some work on it, but this committee could not do very much because of the other work in hand. I believe, however, that you will hear more on this subject from future committees, as it is a matter in which all are vitally interested. There is one point further with reference to the Handbook. It was the original intention of the Executive Committee that at least one copy of this book should be given gratis to each Class A member, but as the work developed we had to increase the size of the book from an estimated 600 pages to nearly double that number, and the expense increased accordingly, so that it became impossible for the Association to finance the publication without making a charge for the books. I would like to add, however, that the prices which have been finally fixed by your Executive Committee are not sufficient to cover the cost of production of this first edition. They may cover it if further editions become necessary, but you must remember in paying these prices that the Association is making a present of part of the book to each of the companies. I hope there is not a company representative here who does not feel that there is sufficient value in the book to make it desirable to take at least one copy home to his company.

The Chairman: The next paper, Meter Installations, by Mr. Severn D. Sprong, New York City, will be read by Mr. Darrah Corbett, of Seattle.

METER INSTALLATIONS

The general problem of metering the product of electricity-supply companies at the customer's premises has been approached from almost every commercial point of view and has received an even wider variety of engineering attempts at solution. It may be admitted at the outset that any sufficiently definite statement of commercial metering requirements can be met by the meter engineers, but underlying all others is the question of the commercial conditions to be met, and just what it is desired to accomplish.

Experience has shown that, under usual conditions, the larger consumer may be supplied at a relatively low investment and maintenance cost for the service equipment on his premises and he is otherwise desirable to such a degree as to entitle him to special rates as determined by his class. However, the number of large consumers forms but a relatively small percentage of the total number of customers on any of the larger general systems. In other words, the retail consumer is much greater numerically than any other single class, and frequently than all the other classes taken together.

The number of installations increases as the size of the meter decreases, although the cost of installation and maintenance remains practically the same, and the significant fact in this connection is that the revenue to the company decreases at about the same rate as the size of the meter. A curve of the cost of customers' installations becomes practically flat at 15 amperes.

Expressing these generalities in actual figures, for a typical case, we may take an aggregate of 35,000 meters which will be subdivided in sizes as follows:

5	ampere meters	20,600	= 58.8%
10	" "	7,100	= 20.3
10-25	" "	5,000	= 14.3
25-75	" "	1,400	= 4.0
100 amp. and above		900	= 2.6
		35,000	= 100.0%

Considering particularly the small meters, which amount to over three-quarters of the total, we find that the cost of installation, but without cost of meter, averages $13. Assuming an

average cost of $15 for the meter, this makes a total installation expense of $28. Taking the low investment and depreciation rate of 10 per cent per year, or $2.80, plus the average cost of a yearly test to the meter of 60 cents, gives $3.40 per year as the investment and maintenance cost of a small meter installation. In the case of the companies that charge a minimum of $1.00 per month, or $12 per year, this shows that 28.3 per cent of their gross income is expended in the maintenance of the installation.

On the other hand the actual results of one of the larger companies which does not charge a fixed minimum show that 10 per cent of the total meters on the system yield an average of 65 cents per month, $7.80 per year, of which 43.6 per cent is expended for maintenance of the meter installation alone. Referring again to the system just considered, it is interesting to note that 40 per cent of all the meters average an income of only $15.45 per year, or $1.29 per month.

The small consumer forms a large part of the total in any one system and is of such importance that notwithstanding the figures given, he is in a necessary and highly desirable class, but one that should be made to yield a greater net return to the company. There are two ways of promoting this: one is the commercial side, which will be left to the consideration of the commercial department; the other is the engineering factors of first cost and maintenance of the customer's installation.

From the foregoing it would appear the truth of the statement has been demonstrated that the cost of maintaining metered service to the small consumer is disproportionately high, often unprofitable, and should therefore receive the most careful attention of operating and meter manufacturing companies.

One point of attack for this problem is through the use of such standard devices as will minimize particularly the items of labor and material used on customers' premises, most of which may be counted as loss in case of discontinuance of the service where it was installed according to the old and generally prevalent methods.

An important consideration in the development of devices to further this end should be the prevention of theft of current. It is general experience that most instances of tampering with meters and services and of outright theft of current take

place at the smaller installations, where obviously the company can least afford any additional losses.

A great deal of intelligent thought and ingenuity have of late years been expended on the question of facilitating the installation and removal of company property on customers' premises, the conservation of loss in the removed material, the adaptability of devices to all sizes of meters and conditions of installation, the facilities for routine tests of the meter, and protection from theft. Operating companies in general have done practically nothing until recently to protect their services against theft, notwithstanding the rapid increase in knowledge of electrical matters on the part of the public. They have profited by but the first part of Mr. Dooley's admonition—"Trust everyone, but cut the cards." More recently, however, as a result of special investigation and attention to the subject, most companies have decided so far as the art permits to also "cut the cards" in the protection of their service.

Meter installations have been in general of a very indefinite character as far as the arrangement of parts and general workmanship are concerned. This condition has persisted and not without some excuse although with very little justification.

Figure 1 shows an installation of this character and Figure 2 the same service after it was changed. Succeeding illustrations show a variety of installation boxes adapted to various forms of alternating-current and direct-current meters on the market. These illustrations are generally self explanatory and need no detailed description here.

There is also shown a simple and commercial form of meter testing block which permits a ready test with artificial load and rotating standard of meters on the customers' premises and without interfering with the service. Diagrams are also given showing the connections for the different classes of meters, which are clearly shown and are self explanatory.

One solution of some of these problems offers itself in the possible development of a really cheap meter, say between $2.00 and $3.00, even if this low price be obtained at the sacrifice of considerable accuracy. Then mount this meter on a sub-base that would be permanently installed on the customer's premises, the meter itself being connected to enclosed terminals in the sub-base by a jack and plug method. It would then be possible

FIG. 1

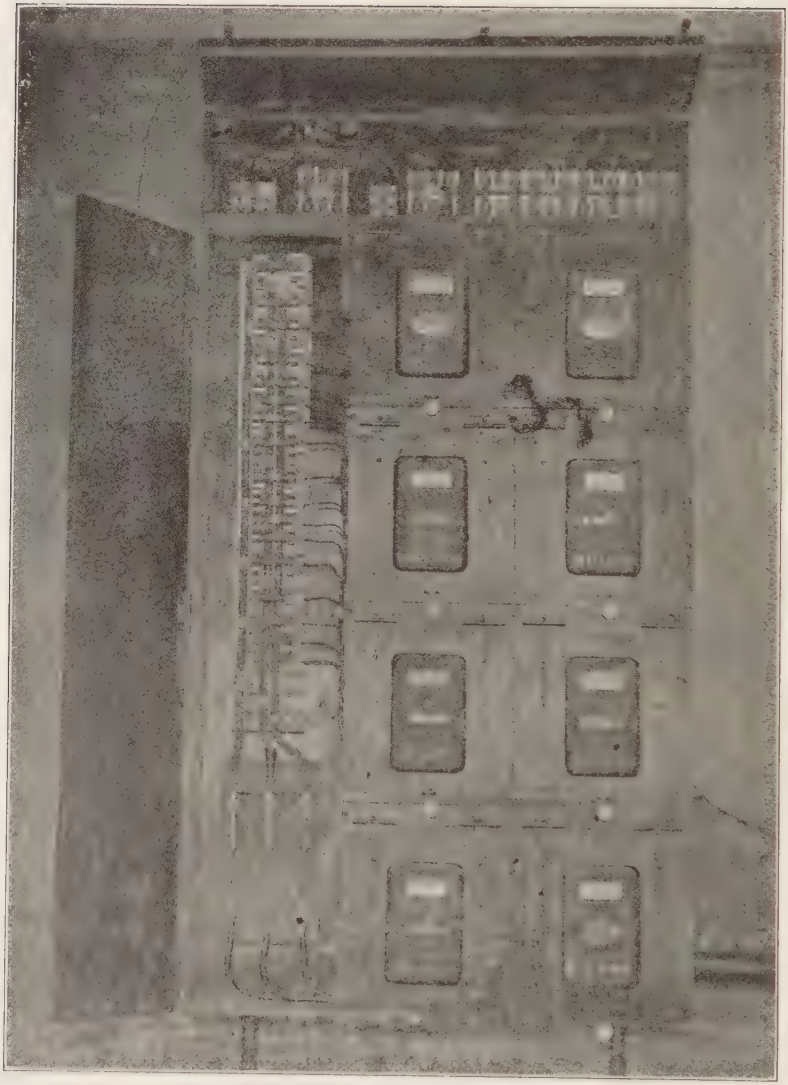


FIG. 2

to make an installation with the minimum of labor and material, provide also for quick removal of the meter for test or substitution, and, in case of discontinuance of the service, the meter could be removed and a blank which would protect the terminals substituted.

The general purpose of this brief resumé of the commercial and engineering conditions effecting the smaller customers is to emphasize the problems involved and to bring them to the serious attention of the manufacturing and operating companies. It seems obvious that under present conditions it costs the operating company too great a percentage of its gross income to do business with the small consumer; that the small consumer makes up a large percentage of the total number of customers and yields a fair percentage of the gross income; that while the commercial department should encourage in every legitimate way the increased consumption of energy on the part of the small consumer, the engineers should endeavor to reduce the cost of installation. Unless substantial gain is made along this line, the lack of it as lamps of still higher efficiency are developed may result in the connecting of all customers below a certain demand on a service charge only, thus reducing to a minimum investment and maintenance cost, meter reading, bookkeeping and billing expenses. This is on the assumption, which may come to be true with high efficiency lamps, that the cost to the company of the energy which the customer might waste if on a flat rate would not equal the total cost of maintaining a metered service.

FIG. 3

Group of General Electric type "C" direct-current watt-hour meters showing the application of protective wiring frame.

FIG. 4

Group of Westinghouse induction watt-hour meters showing application of cut-outs, wiring frames and sealing devices.

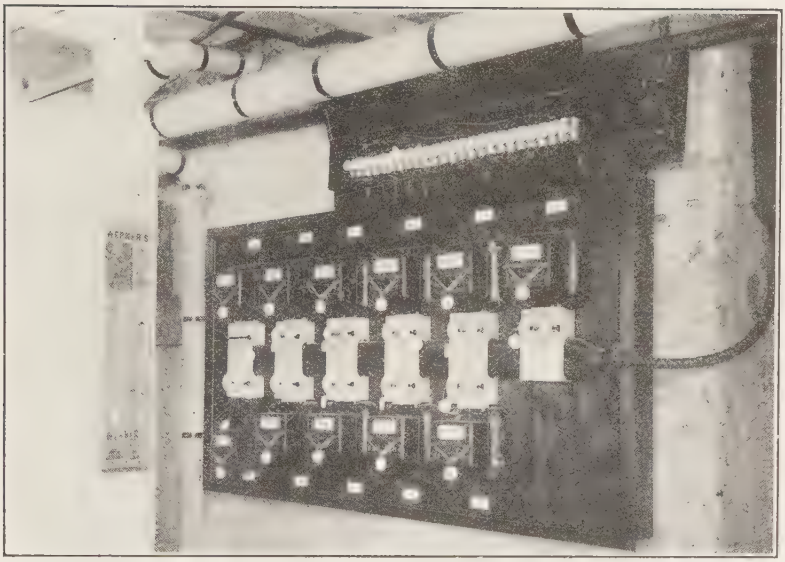


FIG. 5

Group of General Electric Type "I" and Westinghouse type "C E" induction watt-hour meters equipped with protective devices.

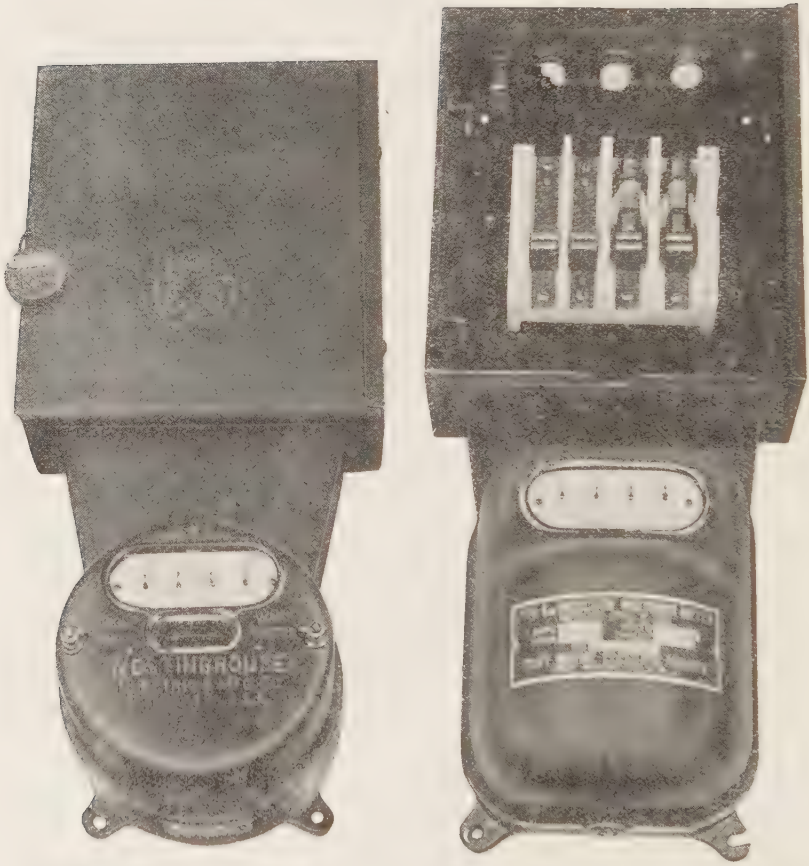


Fig. 6 Protective Service Cut-out Box and Meter Adapter—Type P

Westinghouse type "C" watt-hour meter showing application of protective service cut-out box and meter adapter.

Fort Wayne type "K-3" watt-hour meter showing application of protective service cut-out box and meter adapter.

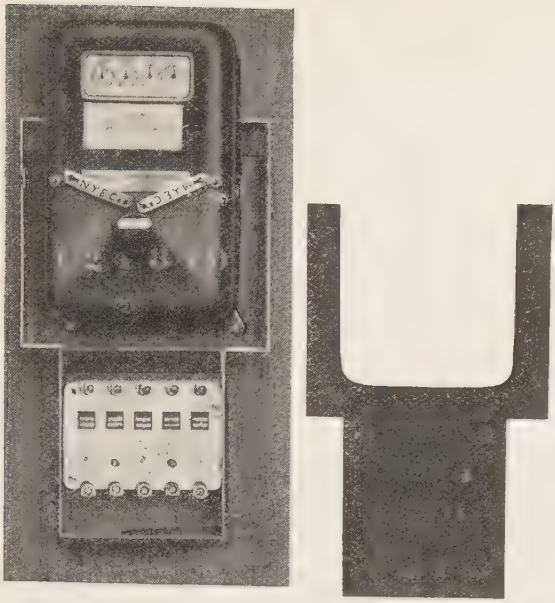


FIG. 7

General Electric Company's type "C" direct-current watt-hour meter equipped with non-magnetic meter frame together with metallic type seal, brass sealing nuts and aluminum name plates—cover removed.

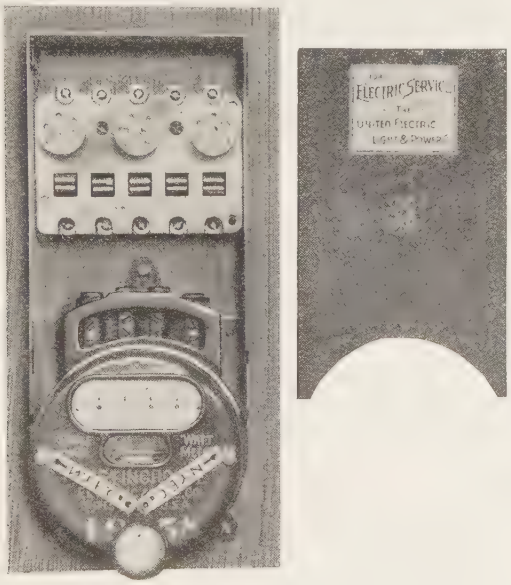


FIG. 8

Westinghouse types "A," "B," "C" or "OA" induction watt-hour meter equipped with meter testing and service cut-out, wiring frames and metallic seal, with brass sealing nuts and aluminum name plate—cover removed.

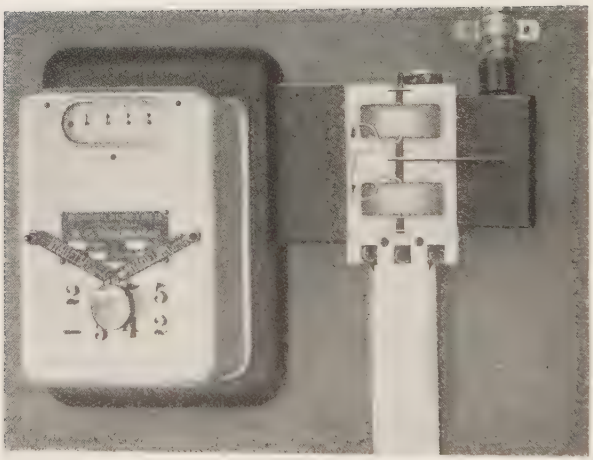


FIG. 9

Westinghouse direct-current watt-hour meter equipped with meter-testing and service cut-out, non-magnetic metal meter frame, terminal protectors, seals, wing nuts and name plates. Under service conditions.

FIG. 10

View of General Electric type "C" direct-current watt-hour meter equipped with protective and meter-testing devices undergoing test. The portable testing plug is inserted in the cut-out, shunting the consumer's load during the test and at the same time making all of the necessary connections for the test of the meter by one single operation; thus the meter may be tested without the necessity of disturbing any of the connections or the interruption of service to the consumer.

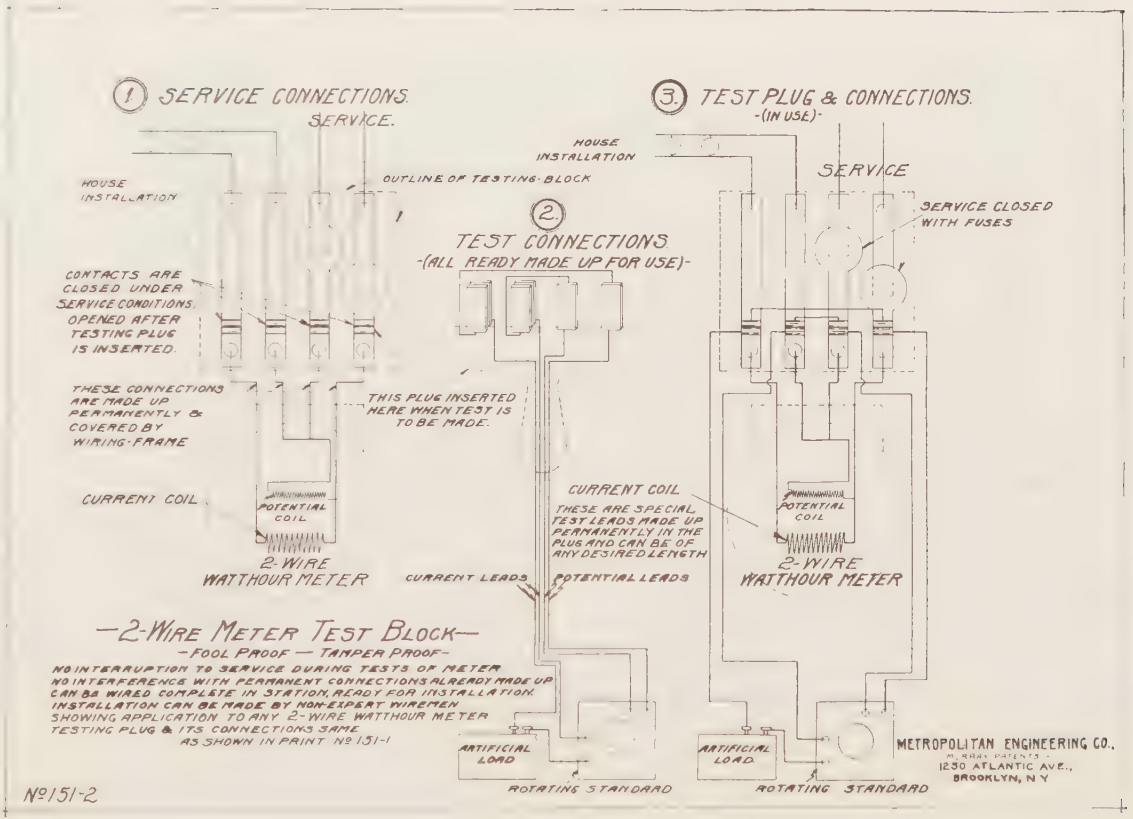


FIG. 11. WIRING DIAGRAM

Diagrammatic scheme of both service and testing connections for 2-wire

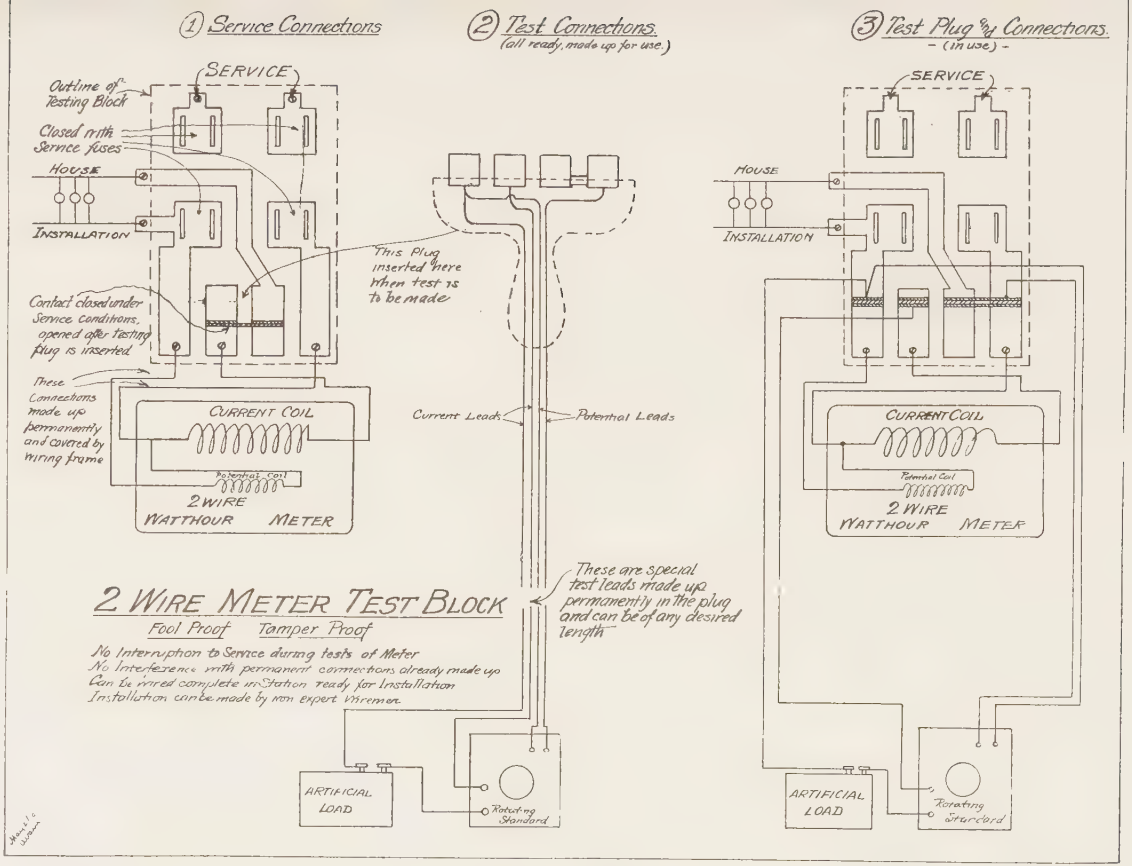


FIG. 12. WIRING DIAGRAM

Diagrammatic scheme of both service and testing connections for 2-wire meters

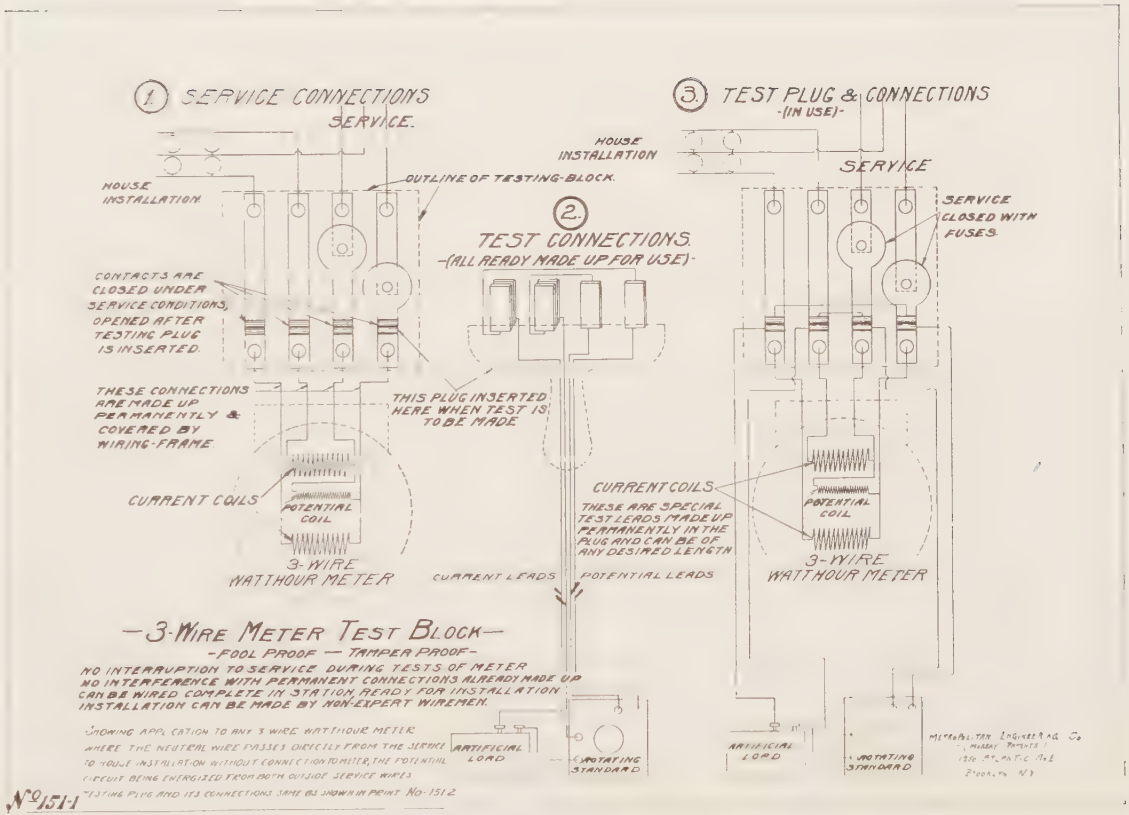


FIG. 13. WIRING DIAGRAM

Diagrammatic scheme of both service and testing connections for 3-wire

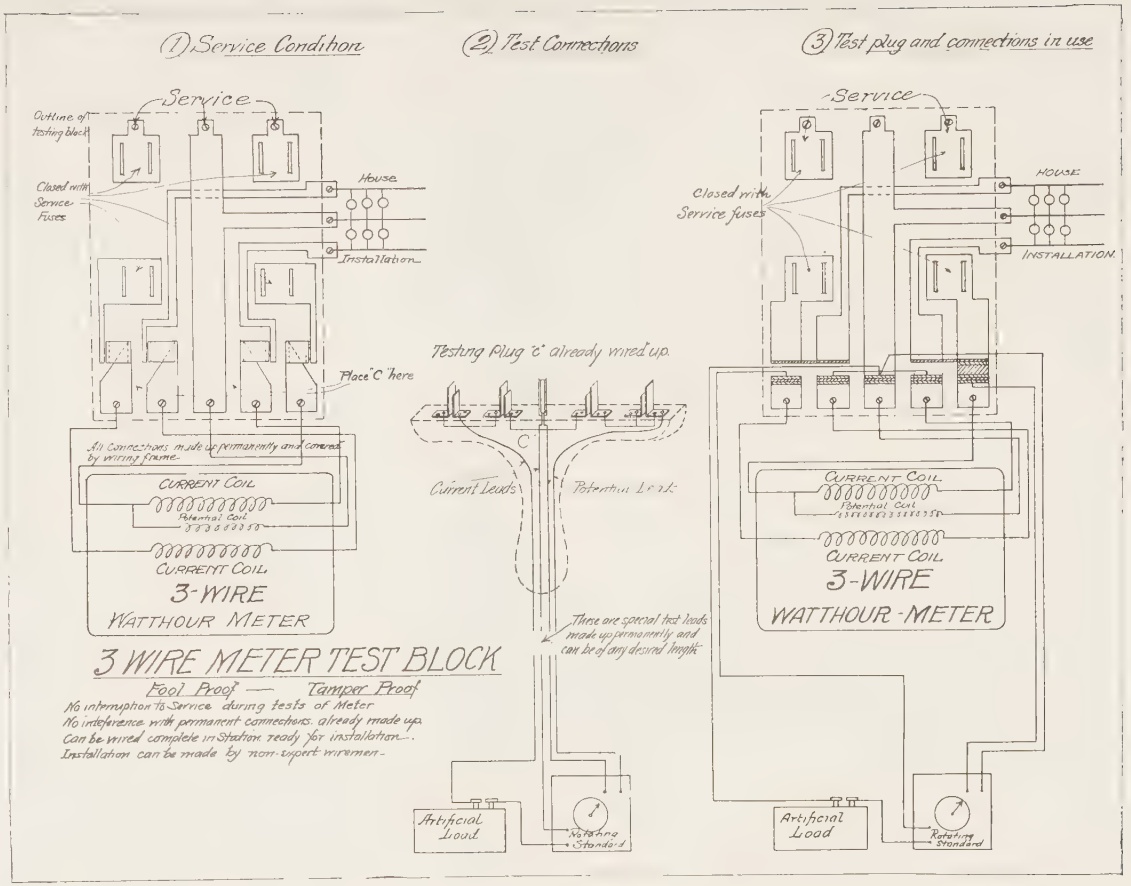


FIG. 14. WIRING DIAGRAM

Diagrammatic scheme of both service and testing connections for 3-wire meters

Meter Test Plug Inserted

Capacity to 30 Amperes

Fig. 15. Combination Service and Meter-Testing Cut-out—Using Plug Fuses. For Two-Wire, Three-Wire or Polyphase Meters

DISCUSSION

Mr. S. G. Rhodes, New York City: Certain figures are given in the paper for the distribution of meters according to capacity on a specific system. For the purposes of discussion the paper will, of course, serve very adequately. It should be borne in mind, however, that possibly different distributions of the sizes of meters could be obtained in different localities. For instance in a suburban community consisting almost entirely of residences and small shops, there would be, of course, a much greater percentage of the very small capacities of meters.

In paragraph 5 the figure of 60 cents for the yearly test of the meter does not cover the item of indexing the meter, its repair or special inspections occasioned by inquiry from the bookkeeper, nor periodic tests at shorter intervals than one year. These are, it is true, details which may be assumed to be covered, but in a careful analysis of the subject they should be properly weighed or accounted for and they show how very conservative and safe are the statements of the author. In paragraphs 4, 5 and 6 one point we believe is omitted, and that is, that a truer basis of comparison would be to reduce the meter capacities to a kilowatt basis (the unit of billing) and to calculate the investment, maintenance and depreciation costs on a kilowatt basis. Such a method would then form a more complete basis of comparison for the various classes of customers.

It seems to be somewhat unfair to charge those having jurisdiction over meter installations with lack of appreciation of proper service conditions. This may be partially correct, but the development of metering devices, which has been only recent, is to a great extent responsible for the possibility of making a cheaper installation at the present time than in the days when haphazard wiring was the practise.

Without attempting at all to advise our Canadian friend, it has occurred to me that those meter-testing devices by which it is possible to shunt the customer's load would serve to give an index of the efficiency at which the meter is operating without breaking the seal. If a meter was found to be more than five or ten per cent slow, or at all fast, it could be taken out; if it was within the company limits it could be allowed to remain as calibrated and as installed.

Mr. H. L. Wallau, Cleveland: The last point brought out in this paper refers to a service charge only, which presumably means the installation of some current-limiting device, such as the flickering device that is used in Hartford. I wish to mention here that the Ohio Public Service Commission, while not having made any absolute ruling against it, has prevented one company from using it, and is generally opposed to it. I do not know how the other commissions feel as to this, but it would be worth while to look into the matter before purchasing any large number of devices and establishing a system of charge based on demand only.

Mr. O. J. Bushnell, Chicago: I appreciate the fact that a man's opinions are largely formed and controlled by the practise of his own company and the conditions which exist where he is employed. I have listened with a great deal of interest to this paper. At the same time, it seems to me that the plan of lessening the cost of service to our small consumers by the installation of expensive meter-protective devices amounts to nothing. I have studied very carefully into this matter the last two or three years, but have been unable to find any way in which the installation of such devices could operate to the reduction of expenses for these small consumers.

Where a meter is installed in premises, as it is now very generally, and left there permanently, the current being simply cut off when one customer goes out and turned on for the new one, you cannot save much in installation expense; and where meters are as accurate as they are now, especially on the alternating-current service, and do not require testing at intervals oftener than two years, you cannot save very much on testing expense; and these are the conditions which control the meters of very small consumers.

However, there is a feature to these devices which I do not want to overlook, the protective feature. This may be necessary in any kind of installation and its value to any particular class of consumers each company must decide for itself. There is great value to these devices in the matter of economy when you use large-sized meters where the testing has to be done at much more frequent intervals, as, for instance, continuous-current meters which must be tested every three months. These devices have been developed during the past year, I am

glad to say, and are now obtainable. It is certainly possible to effect a saving in maintenance expenses by their adoption.

Mr. Rhodes: In some of the smaller companies known to me I have found that meter-testing devices and services have worked a positive economy. It has been possible in these smaller companies to have the meters set on boards, wired at odd times or wired from diagrams by inexpert labor, and passed over to the line foreman. Instead of sending the meter out with a separate gang and possibly an expert meterman to calibrate it afterwards, he had only to introduce the service leads. Then another thing: instead of using two men, as some companies have found necessary, the testing plugs and the apparatus that go with the device make it possible to use a one-man equipment, and instead of the 8 or 10 meters a day under the old method, the new method makes it possible for a single man to test 12, 14 and 16 meters. These economies must be borne in mind when the first cost of the device is considered.

Mr. Peter Junkersfeld, Chicago: I would like to ask the gentleman from Vancouver if he knows of any special reason why, in Victoria, so many meters are installed over the front doors? Is it a government regulation, or is there a special reason why it is done?

Mr. J. Jenkinson, Vancouver, B. C.: I can answer that question. At one time some of our commercial men gave it out to customers that meters should be installed outside, for the simple reason that they could be more easily read and some trouble would be saved. I had nothing to do with that. I superintend the meter business in Vancouver, not in Victoria; I have 33,000 meters connected to the line and I strenuously object to meters being placed on the outside. When we have them outside, as we all know, the damp climate abuses them, the clockwork gets in a dirty condition, and in three years they are not worth one cent to us.

I would like to speak a little further now with reference to the checking of meters. Our friend here has said that the meter should be packed out by an expert meterman and then re-calibrated in the service. Well, that is just where we fall down on the Canadian side. We are not allowed to calibrate them. We calibrate our meters ourselves, it is true, but they still have to pass the government inspector, who in turn cali-

brates them, and we have to put the meter out and take our chance on its working outside.

I think the devices that have been explained for testing meters would be useful to us on the other side; they would give us a chance to calibrate our meters without any interference, but on the other hand, if we found the meters wrong we would have to send another corps of men to bring them in to be opened by the government and tested by the government inspector. You see the position we are in. The rules of the Canadian Government are that a meter tested by them must come in every five years. Now under our present basis of installation—every month now it is 785—handling 700 meters a month, in five years from to-day, we should have 1100 meters coming in. You can see that such a bulk of work would be impossible; we are embarrassed at the present time.

Mr. J. C. Henkle, Portland, Ore.: I think that the attitude taken by Mr. Bushnell is admirable; especially on the larger meters this particular device would facilitate testing. With the advent of rotating standards, I do not believe there is going to be a very great saving in residence testing by means of this, however, not nearly as great as will be effected in the larger installations where it is now necessary to jump with the meters because of the cost of installation.

There is one other point I would like to make: In the installation cost the average is given as $13 exclusive of the cost of the meter. I would like to ask the gentleman who read the paper if he has any information as to just what the $13 is made up from. It strikes me that that is a little high for an average condition, and I would appreciate hearing just how this figure was developed.

Mr. F. G. Vaughen, Schenectady: For the benefit of Mr. Junkersfeld I would like to say that he need not go to Victoria or Vancouver to see the class of installation of which he spoke. He can take a trip in the States and see some installations which are far more crude. Meters are not always on the front porches as he saw them there, but they are outside. In Georgetown, in Jacksonville, all through that country, they never put the meter inside the house. I have no doubt he might see some of them on the Coast. The South is full of just that class of installation.

Mr. Stacy Hamilton, Portland, Ore.: In connection with the use of these protective devices and for the benefit of those few who may not have tried that sort of thing as yet, I wish to offer a little statement of the experience we have had in Portland. We recently constructed an underground system there in the heart of the business district on which we have all sizes, from the very smallest of peanut stands up to our very largest customers, and although we did not install any of the patented protective devices such as are advertised and for sale, we used something that we got up locally, a sort of home-made affair, so to speak, which is very similar to the devices exhibited and which under our conditions was perhaps a little better, while the operating cost was a little lower. It consists simply, as the patented devices do, in using cut-out blocks, the patented cut-out block, or the cut-out block protecting the individual meter with a steel box, and then running the wires out of that iron box through a zinc gutter or connection box to the meter. The wires leave the meter on the right in the open. Our system being continuous current, we do not allow the meters to come in close proximity to the steel cut-out boxes. We carry the service to and into the meter; the customer brings his wires to the right-hand or load side of the meter. We then have this zinc gutter which leads up to the meter from the cut-out box, and the cut-out box itself, both sealed with our regular type of meter seal. We find, however, that people break the seals on those boxes in case of the fuse blowing out, get into the box themselves and fix the fuse. The result is that we go around sooner or later and find the seal to the box open, the cover probably not even closed, and our protection not absolutely lost, but nearly so.

I do not undertake to say that such practises could not be stopped, or that it would not be advisable to force the stopping of them; but I say here is a practical difficulty that is bound to follow the adoption of protective devices.

The Chairman: The next paper is the report of the Committee on Grounding Secondaries, Mr. W. H. Blood, Jr., Boston, Chairman.

REPORT OF THE COMMITTEE ON GROUNDING SECONDARIES

A committee to consider the important subject of grounding secondaries of alternating-current systems was first appointed by the Association in 1907. Similar committees have been appointed from year to year by each succeeding President. The subject at first received indifferent consideration by the member companies, but one after another, as serious accidents and in some cases fatalities occurred in the operation of ungrounded circuits, the managers of the companies have been forced to give the matter careful attention.

The committees, in all of their reports, have strongly recommended the grounding of secondary alternating-current circuits which carry not to exceed 150 volts. The individual members of these committees have, in season and out of season, urged the importance of giving this matter prompt attention, arguing that even disregarding the humanitarian aspect, the assured protection was financially warranted. For the past few years the committees have done hardly more than carry on an educational campaign, although they have gathered statistics from time to time which have strengthened their original views.

Your Committee now has the gratification to report that it has at last been successful in getting all of the interested parties to agree and that there is now a unanimous opinion on the subject.

At a conference held in New York, March 12, committees from the American Institute of Electrical Engineers, Association of Edison Illuminating Companies and National Inspectors Association met with the Committee of the National Electric Light Association. This conference voted unanimously to recommend to the Electrical Committee of the National Fire Protection Association certain changes in Rule 15, National Electrical Code (Edition 1911) upon the subject of grounding secondary alternating-current circuits. The changed portions of the Code rules will read as follows:

> "Transformer secondaries of distributing systems *must* be grounded, provided the maximum difference of

potential between the grounded point and any other point in the circuit does not exceed 150 volts."

"When no neutral point or wire is accessible, one side of the secondary circuit *must* be grounded."

"Where the maximum difference of potential between the grounded point and any other point in the circuit exceeds 150 volts, grounding *may be permitted.*"

"Companies and departments in charge of water-works are urged to allow the attaching of ground wires to their piping systems in the full confidence that the integrity of such piping systems will in no way be affected, whatever may be the normal voltage."

Certain other minor changes were recommended to make the rules consistent and to avoid ambiguity.

At the annual interim meeting of the Electrical Committee of the National Fire Protection Association held March 22, 1912 (the public meeting of this organization now being held only once in two years), the Insurance Expert of the National Electric Light Association presented the resolutions of the conference and asked for a full and free discussion of them. As a result, the Electrical Committee of the National Fire Protection Association voted to approve the recommendations and to present them at the open meeting to be held in 1913 for the purpose of having them adopted and printed in the 1913 Code. It was also suggested that the fullest publicity be given to the proposed changes.

This action will give the electric lighting companies which are not now grounding their secondary circuits nearly a full year in which to bring about the changes and to conform to what is recognized as the best engineering practise, and also to comply with that which, in all probability, will be the requirements of the National Electrical Code in the year 1913.

It will be noted that the rule in brief provides that up to 150 volts alternating-current circuits *must* be grounded and above 150 volts "grounding *may* be permitted." As to the first part of the rule, there is unanimity of opinion; as to the latter part, while there is still some difference of opinion, the wording suggested was unanimously agreed upon as a satisfactory compromise. There are some cases where, with the use of the higher voltages (over 150), it seemed to be questionable which is the safer course to pursue, and for this reason the rule was

so worded as to allow local conditions to govern. It is also recognized that it is impossible to determine within a volt or even within a few volts what is a dangerous and what is a safe voltage to handle under all conditions.

If the rule, as worded, is complied with, it will make practically all of the lighting circuits in the country safe as far as admitting dangerous high-potential currents into the premises of a customer is concerned, for it will limit the voltage to a maximum of that carried by the secondary circuits. It also allows the exercise of a certain amount of discretion with reference to the grounding of the higher voltages, so that local and other conditions may be considered in each case.

The only point of importance now unsettled is with reference to the kind of ground connection to be made. It is admitted by all that a ground made to a metallic water-piping system is as nearly "permanent and effective" as can be had and that it is without question the best that can be obtained. Every effort should be made to utilize grounds of this kind. There are, however, isolated cases, notably in residence lighting in rural districts, where water-piping systems do not exist, where some other forms of ground must be secured. The National Electrical Code allows the use of ground plates and describes the method of installation. Some lighting companies have secured good results by driving galvanized iron pipes into permanently moist soil. Connection with grounded railway return circuits has also worked well in some cities. In other locations none of the above have been "permanent and effective," and a complete return circuit has been run to certain points where elaborate provision has been made for ground connection. Some of the devices, patented and others, on the market if used give false protection because of their high and varying resistances. The Committee believes that a high resistance ground may be worse than none at all and it therefore cautions against the use of such devices.

The Committee further recommends that operating companies keep accurate records of tests on different kinds of grounds, in different kinds of soil, and at different times of the year, in order that during the coming years more accurate data may be collected upon which to base further recommendations.

The Committee urges upon all member companies the importance of giving this matter early attention in order to save their

customers from unnecessary accidents and injuries and themselves from annoying suits and embarrassing judgments.

Respectfully submitted,

Committee { W. H. Blood, Jr., *Chairman*
W. C. L. Eglin
H. B. Gear
Paul Lincoln
W. T. Morrison

DISCUSSION

Mr. Farley Osgood, Newark: There is one statement which the chairman of the committee made that I hardly believe is entirely appreciated. In a few paragraphs of the report he simply relates a fact which is the result of five years of as hard work as has ever been done for the electrical industry. It is another condition of standardization and co-operation with other interests which are allied with us.

On the first page it is stated that a unanimous opinion on grounding has been obtained, and the Association having to do with the code has at last joined with us and made mandatory in its code a rule which we virtually made mandatory for ourselves at the Atlantic City Convention, namely, the grounding of secondaries up to 150 volts potential.

The engineering question as to whether secondaries should be grounded or not has been an open one, a wide open one for a number of years, and opinions of equally good men on both sides have been very decided as to whether a secondary should be grounded or should not be grounded. All the more credit is due to this committee for having brought practically all the engineers to one mind, to such an extent that even our underwriter friends can now see no harm in making mandatory a rule which engineers to-day believe to be the best thing for the electrical business and for humanity in general, and we owe a great deal of thanks to this committee for this extremely desirable result which they have put before us in a few modest statements.

Now as to the operators complying with this rule at once: I think the suggestion of the committee to take it up promptly

is one which we should not hesitate to follow. Our own experience has taught us that when this rule becomes mandatory those companies operating under the jurisdiction of State utilities commissions may be forced to spend their money very quickly in order to comply. The commissions, generally speaking, do not thoroughly appreciate the great amount of money that it is going to take to do this work quickly. However, they feel that if such a rule has been brought about by the consensus of opinion of so many good men, and is also advocated to a compulsory degree on the part of the underwriters, it is their duty to obtain the physical result desired in as short a time as they possibly can. Therefore, anything that can be done to anticipate such requests will be an economy for the companies doing such work.

As a suggestion I would advocate that henceforth all new work being done follow this requirement, namely, that on all new installations from now on the grounding of secondaries be required by the operating companies. That will put a company in the position of being up to the minute in the work which is going on, and it will put them in a most excellent position at law in case of any action.

I cannot say too much in favor of the request of the committee that we all keep careful records of the results of artificial grounds. The only way in which we can help them to give us their best advice is to make tests for them and repeat such tests after periods of a year or more, to give them the benefit of such work.

An artificial ground is not a good thing at best; a poor ground is worse than none, from the safety point of view, and it is up to the operating fellowship to develop what may be determined as a satisfactory artificial ground. We should now do our part toward getting the results which the grounding committee wants from us.

I can say only one more word in praise of the results obtained by this committee; as we go on I know we shall all see more and more that they have accomplished a great work.

The Chairman: This matter, as the last speaker has stated, has been before the Association for a number of years, and has finally been worked down by the committee to a basis which I think we all agree we ought to accept. As it will involve considerable expense on the part of nearly every company it is

a step that should be taken with due deliberation. It ought to be passed on by the entire Association; and the Chair will be glad to consider a resolution recommending that this matter be referred to the Executive Committee for favorable action. That, I think, ought to be done during this meeting.

MR. L. B. FAULKNER, Olympia, Wash.: I would like to ask Mr. Blood if he knows the average cost of grounding secondaries, not accurately but approximately?

MR. BLOOD: The cost varies, of course, a great deal in different cities; in some cities I have known where it ran from six to eight, possibly as high as ten, dollars per customer or per transformer grounded.

THE CHAIRMAN: The question now before you, gentlemen, is what action do you wish to take on this report?

MR. OSGOOD: I offer a resolution that the Report of the Committee on Grounding Secondaries be referred to the Executive Session for action on the part of the proper committee, with the recommendation of this Session that the report be adopted and that its recommendations be made part of the National Electric Light Association's rules or requirements of standard practise.

MR. W. W. FREEMAN, New York City: I second the motion.

THE CHAIRMAN: If you will omit the last phrase I think the resolution will be all right.

MR. OSGOOD: I accept the amendment.

MR. FREEMAN: I second the motion as amended.

The resolution was thereupon put to a vote and unanimously carried.

THE CHAIRMAN: The next paper is the Report of the Lamp Committee, which will be presented by Mr. Freeman in the absence of Mr. F. W. Smith, New York City, Chairman.

REPORT OF THE LAMP COMMITTEE

In presenting this, the report covering the work of the Lamp Committee for the past year or since the last Convention, it may be well at the outset for the general information of members, particularly for the new members of the Association, to review briefly the subject-matter covered by the previous committees in the reports submitted to the conventions.

RÉSUMÉ OF PREVIOUS REPORTS (1909-1911)

The Lamp Committee was added to the list of standing technical committees of the Association during the year 1909, and its first report presented at Atlantic City (see *Proceedings Thirty second Annual Convention*). In this report was submitted a general résumé of the lamp methods and practises of the member companies as compiled from replies obtained by the Committee responsive to a general circular of inquiry sent to each member company. The report summarized these replies from the members and covered the questions as to the several types of lamp used, free renewal practise and other details, with special reference to and comment on tungsten lamps. At that time the carbon lamp was reported as still the standard lamp. It was then the almost unanimous opinion of the member companies, as set forth by the Committee, that the tungsten lamp was the best possible instrument for making satisfied customers. It is interesting to note in passing, in the light of present conditions, that there was no little expression of fear at that time (1908-1909) on the part of the central-station companies as to the effect the introduction of the tungsten lamp would have on revenue, etc.

The report dealt generally with the development of lamp manufacture during the years 1908 and 1909, covered the result of investigations through the electrical testing laboratories as to the relative merits of American-made tungsten and the then available foreign lamps of that type, and other details, the conclusions of the first Lamp Committee being that the metallized-filament lamp would rapidly supplant the carbon type as the standard lamp furnished generally on free renewal basis, and would retain this position for at least several years to come; that every company could afford to offer the best lamps available to its

customers, and that such policy would be productive of better results both immediately and in the future. The Committee advocated in its report at that time an open policy on the part of member companies of offering tungsten lamps to all customers upon favorable terms, with an aggressive campaign for new business.

The second report, submitted at St. Louis (see *Proceedings Thirty-third Annual Convention*), dealt more particularly with the improvements in the tungsten lamp, touching on the question of the methods best adapted in connection with the tungsten lamp for the development of new business; outlined the important changes in lamp efficiency, the markings as to voltages, etc., with comment also on methods of properly introducing the tungsten lamp; the conclusions of the Committee being that, while there was a noticeable decrease in revenue, "as a rule, the customer purchases illumination to fit his purse"; that the reduced cost of lighting would bring additional customers, and that the companies generally reported considerable new business as the result of the introduction of the tungsten lamp.

The third report of the Lamp Committee, submitted at New York, 1911 (see *Proceedings Thirty-fourth Annual Convention*), dealt, especially with the several important developments in the method of manufacturing tungsten lamps, improvements in the direction of standardization of lamp sizes and ratings, additional types, etc., and, in brief detail, with the wire type and drawn-wire tungsten lamps introduced by the manufacturers during the latter part of 1910.

This report advanced the opinion that the carbon-filament lamp had passed its period of maximum usefulness for general lighting service, with particular reference to the sizes equivalent to 16 and 32-candle-power, and that the Gem or metallized-filament lamp was gradually taking the place of the carbon lamp within these limits.

This year your Committee has refrained from sending a general circular to members asking for information, etc., as the basis of its report, and has continued the practise of the Committee for the preceding two years of utilizing the Association *Bulletin* for the purpose of disseminating information of interest to the several classes of members. Articles covering the various phases of the incandescent lamp situation have appeared in the

Bulletin, and at the present writing other articles are in preparation and will appear during the remainder of the term of the present committee.

Lamp Sales

It will be interesting and instructive to members to study the growth of the incandescent lamp business during the past five years, and to note to what extent the development of the newer types of lamp of higher efficiency, etc., has affected the output. The total sales of domestic lamps of all standard types for the year 1911 was, in round figures, eighty-five million (85,000,000), an increase since 1907 of 33 1/3 per cent, the increases being, for the year 1909, 20.09 per cent; 1910, 12.40 per cent; 1911, 8.45 per cent. The following table will show at a glance to what extent lamps of the different types (carbon, gem, tantalum and tungsten) contributed to the total output during this period (1907 to 1911, inclusive):

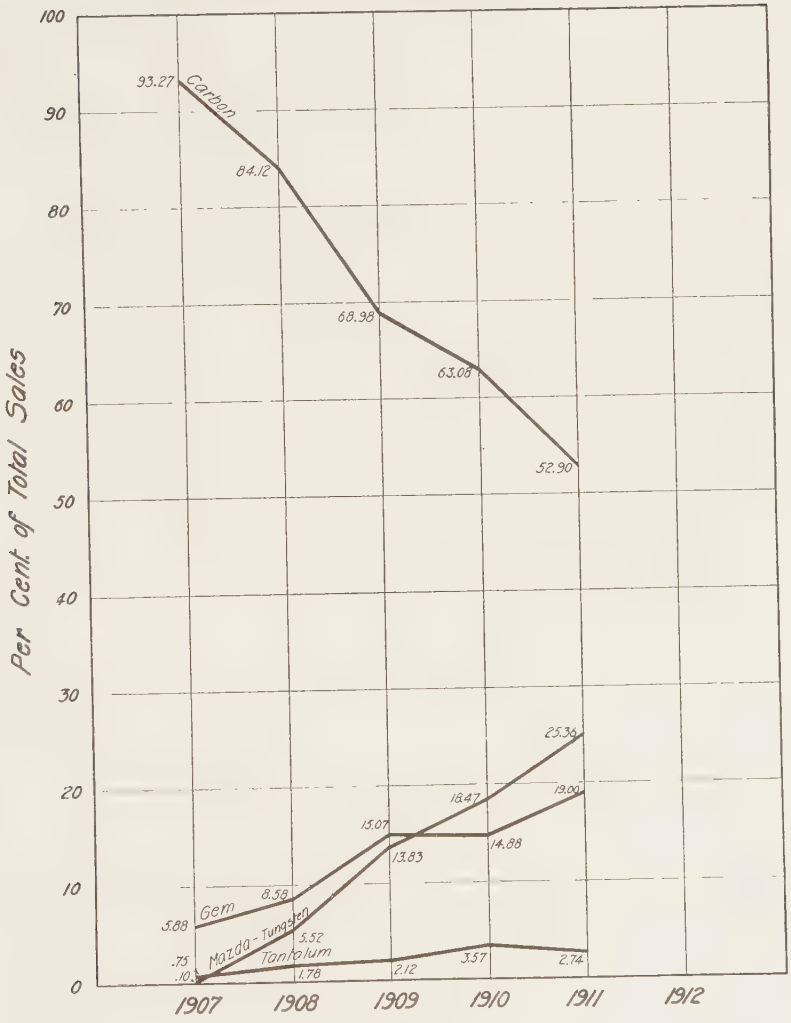
DOMESTIC INCANDESCENT LAMP SALES, 1907-1911, INCLUSIVE

Showing Ratio to Total of Carbon, Gem, Tantalum, Tungsten

Type	1907 Per Cent	1908 Per Cent	1909 Per Cent	1910 Per Cent	1911 Per Cent
Carbon	93.27	84.12	68.98	63.08	52.90
Gem	5.88	8.58	15.07	14.88	19.00
Tantalum	.75	1.78	2.12	3.57	2.74
Tungsten	.10	5.52	13.83	18.47	25.36
Total ...	100	100	100	100	100

As will be apparent, during the year 1907, 93.27 per cent of the total sales of domestic lamps were of the carbon type. Each year thereafter shows a falling off in the output of this type of lamp, with a marked increase in the ratio to the total for the metallized-filament and tungsten types, so that for the year 1911 the carbon lamp had dropped to 53 per cent of the total sales, while the metallized-filament lamp had increased from 5.88 per cent in 1907 to 19 per cent in 1911, and the tungsten lamp from a rather insignificant quantity (.10 per cent) to 25.36 per cent, the tantalum lamp having made but slight progress from the time of its introduction up to and including the year 1910, with a falling off, as will be apparent, during the past year, 1911. This shifting of the product from one type of lamp to another over the past five years, as indicated in the above table, is more graphically shown in the curve herewith.

Curves showing yearly sales
of
Domestic Incandescent Lamps.
1907-1911



Every indication points to a further decrease in the output of the carbon lamp; in fact, the manufacturers report it not unreasonable to expect that during the current year (1912) the output of this type of lamp will be less than 20 per cent of the total, so that the passing of the carbon lamp, which has held the field so well and for so many years, may now be predicted. The demand for the tantalum lamp is further decreasing; the current year will, no doubt, show a still greater falling off in the output of this type of lamp.

With the first introduction of the Gem or metalized-filament lamp the comparatively high prices then existing, occasioned by the small production, limited to a considerable extent the adoption of this type of lamp for free renewal by the central-station companies. Under present conditions there would seem to be no good reason for the reluctance of central-station companies to take up the metalized-filament lamp, and your Committee earnestly recommends that all member companies, small and large, adopt the Gem or metalized-filament lamp in place of the carbon. In connection with this recommendation on the part of your Committee, attention of the member companies is called to an article on this subject published by the Committee in the March (1912) issue of the Association *Bulletin* under the heading "The Use of Gem Lamps by Central Stations." It may now be said that the field is covered by the Gem or metalized-filament lamp in all the important types and sizes.

Development

As previously set forth, the Lamp Committee in its report last year (May, 1911) touched on the drawn-wire and wire-type tungsten lamps, which had then reached an important stage in their development. Early in 1911 the production of lamps of the pressed-filament "hair pin" construction was discontinued by a majority of the manufacturers, and after June of that year no shipments of this type were made by them; one manufacturer, however, continuing with the wire type continuous pressed-filament lamp described in the report of last year.

Both the drawn-wire and wire-type tungsten-filament lamps have been still further greatly improved, particularly as to mechanical strength. Tests made by submitting the lamps to repeated and violent shocks show that these lamps as now manu-

factured satisfy every reasonable requirement as to robustness and ability to meet all commercial conditions of use, both as to position of lamp and resistance to ordinary shock or vibration. The lamp is now giving general satisfaction in lighting service.

Very recently a marked improvement in tungsten lamps of 250, 400 and 500-watt, of 100 to 130-volt, has been made, permitting the standardization of these lamps at an efficiency of 1 watt per candle, while attaining a useful laboratory life of approximately 1000 hours with good maintenance of candle-power, and it would seem that these higher candle-power units should find a more general field of usefulness.

Efficiency and Life

The improvements to the tungsten-filament lamp in ruggedness, maintained candle-power and burn-outs have made it possible to standardize the useful life at improved efficiencies. The lamps are marked with the three different voltage ratings as heretofore. The useful life, efficiency and candle-power, when burned at the different voltages, are shown in the following table:

HIGH OPERATING EFFICIENCY (Top Voltage) Average Life, 1000 Hours			MEDIUM OPERATING EFFICIENCY (Middle Voltage) Average Life, 1300 Hours			LOW OPERATING EFFICIENCY (Bottom Voltage) Average Life, 1700 Hours		
Watts	Eff.	C. P.	Watts	Eff.	C P.	Watts.	Eff.	C. P
15.0	1.30	11.5	14.5	1.36	10.7	14.0	1.42	9.9
20.0	1.25	16.0	19.3	1.31	14.8	18.8	1.36	13.8
25.0	1.17	21.4	24.4	1.23	19.8	23.5	1.28	18.4
40.0	1.12	35.7	38.6	1.17	33.0	37.4	1.22	30.7
60.0	1.10	54.5	58.0	1.15	50.5	55.7	1.20	46.5
100.0	1.07	93.4	96.7	1.12	86.4	93.6	1.17	80.4
150.0	1.05	143.0	145.0	1.10	132.0	140.0	1.14	123.0
250.0	1.00	250.0	242.0	1.05	232.0	234.0	1.09	215.0
400.0	1.00	400.0	387.0	1.05	370.0	374.0	1.09	344.0
500.0	1.00	500.0	484.0	1.05	463.0	469.0	1.09	430.0

The Average Hours Life heading in the above table represent the life when the lamps have depreciated to 80 per cent of initial candle-power.

Electric Sign Lighting

The development of the electric sign business throughout the country has received considerable stimulus from the very satisfactory results obtained by the use of special tungsten sign lamps. A number of the larger companies report a marked increase in the sign business due to these newer type of lamps. In order to make the lighting unit small, and yet sufficiently robust

for this class of service, the lamps are manufactured to burn at from 10 to 13 volts, having an approximate efficiency of 1.35 watts per candle, and are now manufactured to consume as low as 2½ watts per lamp. A large number of the 5-watt lamps of this type have replaced carbon lamps for sign work, and the use of the 2½-watt lamp is increasing, especially for the larger and more elaborate display signs.

For operation on alternating-current circuits the lamps are connected to multiple circuits, and the low voltage supplied through the medium of a special low voltage transformer connected to the distribution circuit, and usually wound for a ratio of 10:1. Where direct-current is supplied the lamps are connected across the circuits in series of ten each.

The manufacturers use special care in the selection of these tungsten sign lamps, and an order should state "series burning," if the lamps are to be used only in straight series, and "multiple burning," if the lamps are to be used on compensators or transformers, as the series burning lamps will not give satisfactory service on multiple circuits, nor will multiple burning lamps give satisfactory service when burning in series.

The lamp manufacturers advise that the output of the tungsten sign lamp has greatly increased since the first of the year, and that during the past few months the sales for this type of lamp for sign work have overtaken the sales for 4 c.p. and 8 c.p. carbon lamps.

New Types of Lamps Standardized

Since May 1, 1911, several new types and sizes of lamps have been announced by the manufacturers as additions to the standard lines. These new types are indicated in the following table:

GEM OR METALIZED

30-watt Gem, 100-130 volts S-17 bulb.

NOTE.—The range of voltage for all Gem lamps, heretofore 100-125, has been extended to 100-130 volts.

TUNGSTEN

15-watt	regular,	100-130	volts,	S-17	bulb.
20	"	"	100-130	"	S-17	"
15	"	round,	100-130	"	G-18½	"
25	"	"	100-130	"	G-18½	"
25	"	tubular,	100-130	"	T-10	"
25	"	regular,	200-260	"	S-19	"
40	"	"	200-260	"	S-21	"
40	"	round,	200-260	"	G-30	"

2.5-watt tungsten sign, 10-13 volts, S-14 bulb.
5 " " " 10-13 " P-12½ " candelabra, screw-base only.
10-watt tungsten, train lighting, 25-34 volts, G-18½ bulb.
10 " " " " 59-65 " G-18½ "

NOTE.—The range of voltage for all tungsten lamps, heretofore 100-125, has been extended to 100-130 volts.

The range of voltage for all tungsten lamps heretofore 200-250 has been extended to 200-260 volts.

STREET RAILWAY

35-watt gem, 100-130 volts S-19 bulb.
54 " " 100-130 " S-19 "
23 " tungsten, 100-130 volts, S-19 "
36 " " 100-130 " S-21 "

ELECTRIC VEHICLE

15 and 25-watt tungsten, 21-65 volts, G-16½ or G-18½ bulb.
15 and 25 " " 66-90 " G-18½ bulb.

STREET SERIES

40 and 80-cp tungsten added to the 4.0, 5.5 and 6.6-amp. ranges.
3.5-amp. range tungsten of 32, 40, 60 and 80-cp.
7.5 " " " " 32, 40, 60, 80 and 200-cp.

Information is at hand which indicates the possible development within a reasonable time of a lamp of lower wattage than 15 for use on circuits of standard voltage.

New Selling Plans—Prices

Under date of March 1 last, the manufacturers announced an entirely new selling plan for the distribution of their product, designed to observe the terms of the final decree laid down by the United States Circuit Court and entered October 12, 1911. Under this new plan the unpatented carbon lamps cannot be aggregated with the patented lamps, namely, metallized-filament, tungsten and tantalum lamps, under one contract to determine the values on which prices are based. This announcement on the part of the manufacturers included new prices and discounts, the prices in general representing a reduction.

Standard Volt and International Candle

The subject of the new values on standard volt as adopted by France, England and the United States, and also the new international candle adopted as the standard of luminous intensity by the same nations, is covered in a report to be submitted at this Convention by Dr. A. E. Kennelly, Chairman of the Committee on Electrical Measurements and Values. This report treats the

subject from the view-point of the effect which these important changes will have on the industry and the members generally, and for convenience of reference will be found printed within the Report of the Lamp Committee.

Introducing the Tungsten Lamp

The practise by central-station companies of introducing the tungsten lamp, particularly for the development of new business, by the system of a wiring campaign which includes the complete equipment of wiring, lamps, fixtures, etc., at a fixed price, subject to payment by the consumer on a weekly or monthly installment basis, continues and seems to be increasing. Two important companies report securing during 1911 an aggregate of twenty-five hundred (2500) new installations, producing satisfactory revenue and prompt payment of bills, including the installment on the wiring, and covering some fifty (50) different classes of business previously devoted to the exclusive use of gas. This system of financing on the part of the company seems to appeal to the small tradesman and secures a class of business difficult, if not impossible to obtain under ordinary methods.

Your Committee feels that it should at this time again urge the member companies to follow a broad and liberal policy with their consumers in order to encourage the adoption and use of the tungsten lamp. Those companies which from the first introduction of the higher efficiency lamps offered them to their consumers on favorable terms, with an aggressive campaign for new business, reaped their reward early, as any temporary loss that may have been felt in revenue was soon more than off-set by the addition of new business, longer hours of burning and better satisfied customers.

CONCLUSION

We commend to the attention of the membership the fact that the incoming Lamp Committee can be of great service in keeping them advised as to the development of the lamp industry, not only with regard to the incandescent lamp, but to other forms of illuminants as well; that the work of the Committee might well be broadened so as to take in the entire field, and that members should avail themselves of this service.

We recommend the continued and broader use of the Association monthly *Bulletin* for the dissemination of information to our members. Through this medium early and up-to-date information put out by the Lamp Committee as authoritative would reach all the members promptly.

The Committee desires at this time to express to the gentlemen who have so kindly and ably assisted in the work throughout the year and in the preparation of this report its great appreciation of the helpful suggestions.

Respectfully submitted,

Committee
- Frank W. Smith, *Chairman*
- W. W. Freeman
- W. H. Johnson
- G. F. Morrison
- F. M. Tait
- F. S. Terry
- E. E. Witherby

DISCUSSION

The Chairman: We are very fortunate in having present at this session a gentleman who has probably devoted more time than any other individual to the investigation of the incandescent lamp from the point of view of the central station and who has presented more reports on this subject than any other one man. I feel that we are favored, as Mr. Lieb is to open the discussion on this report.

Mr. J. W. Lieb, New York City: Many of the matters referred to in this report are worthy of the most careful consideration by the electric lighting companies and while I have not prepared any written discussion, I am glad of the opportunity to emphasize one or two references in the report.

In the diagram on page 317 and the reference thereto on page 316, it appears clearly that the carbon lamp has about reached the limit of its usefulness.

In the early stages of the introduction of the gem lamp, certain difficulties were found which unfortunately checked the rapidity of its introduction. These difficulties have been removed, and the lamp can to-day be considered as in every way

the equivalent of the carbon lamp in its life and holding up of candlepower, with the attendant advantage of increased efficiency. That, together with the reduction in price of the lamp which has come about, makes it encumbent upon the central-station companies to hasten the exit of the carbon lamp and to bring about, as far as possible, the recognition of the gem lamp as the standard lamp of the industry.

Now that will be of advantage to the member companies and to the manufacturers, as they will not be obliged to manufacture and carry in stock so many different types of lamps. If it is found practicable, as should be the case with these improvements, to standardize the gem lamp, using the other high-efficiency lamps in their respective fields of usefulness, it will be possible to increase greatly the output of these lamps, improve their quality and lower their cost. It is, therefore, manifestly to the interest of the member companies to hasten the change from carbon to gem lamps, following the practise of some of the larger companies, who some years ago effected a complete substitution of gem lamps for carbon lamps, and have been supplying only gem lamps in their regular free lamp renewals.

Reference is made on page 319 to the improved efficiency of tungsten lamps, and looking at the table and following the course of the improvements in metal-filament lamps, it is hardly necessary to say that the end is not yet, and undoubtedly in the very near future some further improvement in lamp efficiencies, with maintenance of the present life, may be looked for. Of interest would be a marked improvement not only of the efficiency, but also of life and holding up of candlepower in the smaller sizes which has already been attained in the more recent product of the larger types of tungsten lamps, the 100- and 250-watt lamps. The effect which the perfection of these larger sizes of lamps with improved efficiency, long life and holding up of candle-power, will have in rapidly displacing the old forms of carbon enclosed arc lamps it is hardly possible to prophesy. The advantage which these higher efficiencies of tungsten lamps have given to the central-station companies in opening up to them a field of street lighting, under conditions where the old types of arc lamps have hitherto been inapplicable, will be enormous. The increased and widespread use of tungsten lamps for street lighting in the minor and side streets, the intensive

forms of arc lighting being restricted to the larger avenues and boulevards, wide streets and large areas, opens up practically a new field for the application of central-station current, and with the improvements which are here referred to, and other developments which are under way, a very profitable period of growth is in sight for the central-station industry.

Reference is made in the paper to the smaller sizes of tungsten lamps. I feel quite sure the lamp people will agree with me, that we are far from having reached the limit of what will be found practicable in the near future, although it may not seem commercially possible at the moment to produce lamps of 10 candle-power or less. Some of our companies have found it difficult where they have 110-volt, continuous-current service, to supply the requirements in the direction of sign lighting with small tungsten units. There has been an application of economy coils and transformers in the case of alternating-current service, or the use of series or multiple series circuits for continuous-current service, with a result not altogether satisfactory in giving the highest standard of lighting service. There is a demand in the direction of lower candle-power units in standard voltages for application in signs.

This lamp report refers to the question of free lamp renewals and how important that policy has been to the industry. It is undoubtedly true that the continued striving after higher and higher efficiency in the case of metallic-filament lamps, and the fact that the improvements have been developed in the direction of higher efficiency rather than of lengthened life, has somewhat delayed or made more difficult the consideration or prospective application of free lamp renewals with tungsten lamps.

To a certain extent and from some points of view that is unfortunate, because it does seem as if the supplying of free lamp renewals, where it has been found practicable to use that system, has been of very great advantage in maintaining high standards of candle-power and the highest standard of lighting service by the companies. In that respect our own practise differentiates itself from European practise where free lamp renewals are rather the exception; and this is very much lamented by our European friends and central-station engineers. In the early days they were prevented from adopting the policy of the

company supplying the lamps on account of the hesitancy of government and municipal authorities to place in the hands of a local central-station company the monopoly of the supply of incandescent lamps in its territory. There was, therefore, a tendency toward not allowing the station companies to include the cost of lamp renewals in their charges for current. Many of them have, however, with more liberal conditions prevailing, come to including free lamp renewals in their charge for current. It seems to me that anything that will preserve the highest standards of service and of candle-power, giving to the customer the possibility of maintaining the most efficient lighting units at the lowest cost, must be of decided benefit to the industry generally.

The idea that the customer, every time a lamp burns out, has got to put his hands in his pocket, go out and buy a new lamp, is apt to result in a notable depreciation in the standard of lighting service, and the result is unused sockets and poor lamps, the customer hesitating to make the immediate investment for new lamps. It is to our interest that the customer shall have always in service at the lowest possible cost, the maximum amount of illumination necessary for the least possible money, and that the service shall always be maintained at the highest possible illuminating standards. The committee is to be congratulated that it emphasizes this repeatedly, recommending to the companies that they continue to maintain and preserve for the electric lighting industry the prevailing high standards of illumination. [Loud applause.]

The Chairman: This session is also fortunate in having present the leading lamp engineer, and I think the first incandescent lamp engineer in this country—Mr. John W. Howell, of Newark. [Applause.] I do not know that he will wish to say anything, but we shall be honored if he will do so.

Mr. Howell: What I may say will be the view of an engineer and not of a commercial man. To my mind the present time, as both Mr. Lieb and the report have stated, is witnessing the passing away of the carbon lamp. The old standard lamp which has lasted us for 30 years is dropping out.

Your committee recommends the use of the gem lamp in place of the carbon. I think that recommendation should be

qualified. The gem lamp has a very limited usefulness as compared with the tungsten lamp, and I think the recommendation should be limited likewise. A tungsten lamp can be made of equally good quality or nearly so, from very small sizes to very large sizes. The tables here show lamps of 15 watts at standard voltage up to 500 watts, whereas the gem lamp has a very much narrower range of manufacture and of usefulness. The paper speaks of the very excellent results which have been achieved with 400, 500 and 250-watt tungsten lamps. The gem lamp has no substitute for these, but there are lower sizes of lamps. The 100-watt lamp, for instance, and the 150-watt lamp, are made excellently well in tungsten while in gem they are not correspondingly good. The gem filament is limited to a narrower range of manufacture. I would recommend that the larger sizes of gems be not used, but that they be replaced with the 100 or the 150-watt tungsten lamps.

Again, the limitations of the gem lamp appear in the lower sizes. At standard voltage 30 watts is a small gem lamp, and the performance of these 30-watt lamps is not as good as the others. The report favors a 15-watt tungsten lamp and this lamp has been reported on by committees here and is good; it is very good; and as Mr. Lieb says, still smaller units will probably be available soon. They certainly will be. They are making a great many 10-watt lamps now, and while they have not been placed on the lists and standardized, they are to be, and the 10-watt lamp is a good lamp and is going to be very useful. The only reason for using the gem lamp at all is the expensiveness of the tungsten lamp, and what we have been in the habit of calling its fragility. Now the expensiveness of the tungsten lamp is a result of temporary conditions. We have watched the price go down surprisingly, and it will continue to fall. The fragility of the lamp has also changed very greatly. As the report states, the lamps are now satisfactory and will stand all the ordinary shock of vibration. The strength of the tungsten lamp is good and is getting better all the time so that we have changed our method of packing, and the lamps that you get in the immediate future will not have cotton batting around them. That will enable us to pack twice as many in a box, will facilitate handling, require less storage space and in other ways will tend to cheapen the product.

Other improvements are being made which will still further strengthen the tungsten lamp. We have made a great many lamps in the factory which are very much stronger than those sold at present, and it is only a matter of time, to give us the chance to work these things out practically and commercially, when the tungsten lamp will be just as strong as the carbon lamp. It will be packed the same way and shipped and handled the same way. Then, just as soon as the price comes down a little further the gem lamp will pass away as the carbon lamp is now passing away.

On page 320 of this report the development of sign-lighting lamps is mentioned, and one statement is made which, while perfectly true when it was written, is no longer so. I refer to the statement, "if the lamps are to be used only in straight series, and 'multiple burning,' if the lamps are to be used on compensators or transformers, as the series-burning lamps will not give satisfactory service on multiple circuits, nor will multiple-burning lamps give satisfactory service when burning in series," etc. That condition has changed, and the change has been brought about by increased facilities for making the tungsten filament. The drawing of that tungsten wire was what we called a brute of a job. It was very, very difficult to draw, and the struggles that we passed through to get the wire out and to make the lamp, nobody knows but ourselves. At the present time, however, it is our practise to draw it down to just exactly the size we want, and then stop. We have what we call the single-sized wire; only one size wire is used now in one type and in our sign lamps only one size of tungsten wire is used, absolutely only one. Any and all sign lamps of recent manufacture can be used indiscriminately in a multiple of series, and all will give good service. That will help the sign-lamp business, as we all know.

That same advantage of being able to draw wire down to a definite size and exactly the size wanted assists us in other ways. We have always been obliged to use for 25-watt, or 40-watt lamps wires of somewhat different sizes, not greatly different, but somewhat different. Until now the necessity of using these varying sizes of wire for each type has made it necessary to vary the candle-power and voltage in order to get the desired efficiency. With the single size of wire we can make our lamp

within much narrower limits of voltage and candle-power, which will increase our facility to manufacture and will also help decrease the cost of the lamp, as all these things do.

That same one-sized wire is now used in street-series lamps. If it is commercially desirable we can make all of our series lamps exactly six point six, five point five or any other ampere, and avoid the varying amperes which we have until recently been obliged to make.

In fact, to my mind the adaptability of the tungsten to filament-lamp making is almost perfect. We can make a 10-watt lamp, we can make a 1000-watt lamp, and they are both good. I believe that it is only a question of a very few years when, instead of four lamps on that table, there will be but one, and that the tungsten. The tantalum and gem will have passed away. [Applause.]

The Chairman: Most of the things that Mr. Howell has told us in the past have come true. I have no doubt these will.

We will pass to the next report, that on Electrical Measurements and Values, Dr. A. E. Kennelly, Cambridge, Mass., Chairman. I have asked Mr. Howell if he will present the report, as Doctor Kennelly has not been able to get here.

REPORT OF THE COMMITTEE ON ELECTRICAL MEASUREMENTS AND VALUES

THE EFFECTS OF RECENT OFFICIAL MINOR MODIFICATIONS IN THE UNITS OF CANDLE-POWER AND VOLTAGE UPON THE PERFORMANCE OF INCANDESCENT LAMPS

As is very generally known, certain small changes have been made in recent years, through the official action of the Bureau of Standards, in its relations with other national laboratories abroad, in the standard of luminous intensity, or candle-power, and in the concrete standard of voltage. The candle has thus been slightly changed, and likewise the volt, in order to bring about a more nearly complete international uniformity. The changes have been too small to be noticeable industrially under ordinary working conditions, and would thus be likely to have escaped general notice, if attention had not been directed to them. Nevertheless, they are definite changes, readily capable of being detected in the laboratory; so that it is interesting to consider their magnitudes and directions in relation to incandescent lamps and lighting.

The first change in order of date was on July 1, 1909, when the Bureau of Standards,* with the consent of the American Institute of Electrical Engineers, the National Electric Light Association, the Illuminating Engineering Society and the American Gas Institute, lowered the value of the unit of candle-power by 1.6 per cent, so as to come into conformity with the compromise value agreed upon with the national laboratories of France and Great Britain.† Since that date, the change of standard has become general in this country, and at the same time, our lamps have the advantage of resting upon the same candle-power basis as those of France and Great Britain. Since the change lowered the unit of candle-power 1.6 per cent, lamps then in existence assumed, by virtue of the change, 1.6 per cent more candle-power, and a 10-cp lamp correctly calibrated on the old basis became a lamp of 10.16-cp on the new basis. Or, a

* Bureau of Standards Circular No. 15, May 20, 1909.

† Report of Sub-Committee on Nomenclature and Standards of the Illuminating Engineering Society, 27th September, 1909, *Trans. Ill. Eng. Soc.*, Vol. IV, No. 7, October, 1909 pp. 521-531.

carbon-filament 3.1-watt per m.h.c.p. lamp giving say 16 candles, at 110 volts, on the old basis, would call for a reduction in terminal voltage of about 0.3 per cent or to 109.7 volts, in order to give 16 candles on the new basis. Or, again, the watts consumed in such a lamp would have to be reduced about 0.5 per cent, in order to bring the candle-power down to its proper value in the new unit. In terms of carefully made laboratory measurements, therefore, the change in the unit of candle-power gave the consumers a nominal increase in light and in candle-power, to the extent of 1.6 per cent on all lamps then in service; since, of course, no attempt was actually made to lower the service voltage, and no change occurred in the structure of the lamps. As new lamps have come into existence, since that date, there has been a consequent average reduction of 1.6 per cent in light and in candle-power; although the natural and inevitable variations in service voltage would overshadow such a relatively small change. On the other hand, the new lamps would have an advantage over the old lamps in duration of serviceable life, and in maintenance of candle-power. The increase in serviceable life-time to 80 per cent of the normal initial intensity would, in the case of a carbon-filament 3.1-w.p.m.h.c.p. lamp, probably amount, on the average, to about 7 per cent under carefully maintained laboratory conditions. That is, lamps of the same quality, voltage and nominal candle-power, made since the change, would average 1.6 per cent less in light and candle-power, but about 7 per cent more in serviceable duration of life.

On January 1, 1911, the Bureau of Standards, by international agreement, introduced a slight change in the concrete standard volt.* The change came about as the result of international conferences over the strict definitions of the fundamental electromagnetic standards. The electromotive force of the Weston normal cell was changed in rating from 1.01913 volts at 20 degrees, to 1.01830 volts at 20 degrees C., a reduction of 0.08 per cent; or, expressing the same fact in a different way, the new standard volt became increased in magnitude by this same 0.08 per cent. The standard ampere became likewise a larger unit to the extent of 0.08 per cent; and the watt or unit of power became increased by 0.16 per cent.

*Circular No. 29 of the Bureau of Standards "Announcement of a change in the value of the International Volt," Dec. 31, 1910. See also *Proc. Am. Inst El. Engrs.*, Vol. XXX, No. 2, February, 1911, pp 343-356; "The International Electrical Units, 1893-1910," by E. B. Rosa *Proc. Am. Inst. El. Engrs.*, July, 1910, Vol. XXIX, No. 7, pp. 1325-1334.

It is evident that the effect of the change in the volt would necessarily be to increase the actual potential difference applied to a lamp supplied at a nominal voltage of say 110 volts. The 110 new volts would be 110.09 old volts, and, in the case of carbon filament 3.1-w.p.m.h.c.p. lamps of 16-cp, the effect of this would be to increase the candle-power and light by about 0.5 per cent under laboratory conditions.

The direction of the effect produced by the change in the volt in 1911 was, therefore, opposite to that produced by the change of the unit of candle-power in 1909; but of the two, the candle-power change was the greater; since in the case of untreated carbon lamps it corresponded to a lowering of voltage by 0.3 per cent, while the change of 1911 raised the voltage slightly less than 0.1 per cent.

We are informed by Dr. C. H. Sharp, of the Testing Laboratories, New York City, that both the change of candle-power and the change of voltage went regularly into effect at the testing laboratories in New York, without any difficulty, and that no serious inconvenience has resulted therefrom. On the other hand, we all enjoy the advantage of uniform international standards of voltage, current, power and luminous intensity; whereas previously incandescent lamps were found to have ratings that were slightly, but nevertheless distinctly, different in different national laboratories.

Respectfully submitted,

A. E. Kennelly, *Chairman*

DISCUSSION

Mr. Lieb: It will be remembered that a part of these changes that Doctor Kennelly refers to, particularly in reference to the change in candle-power, came about through efforts in which this Association participated, in co-operation with the American Institute of Electrical Engineers, the Association of Edison Illuminating Companies and the Illuminating Engineering Society, they bringing together the standards which were in use in this country, France and England, particularly in the important gas-lighting and electric-lighting branches of the industry. This equivalence of illuminating standards in their

fundamental commercial candle-power units is now an established fact, and commercial illuminating standards in France, Great Britain and the United States are directly comparable. It is hoped that at some succeeding international congress, international action may be possible along these lines.

Doctor Kennelly states that this change has been made without much difficulty. Of course, that is a comparative phrase. As a matter of fact, where the lamps have been tested and standardized under specifications, a large amount of inconvenience has been caused by this change, first in the candle-power standard, and then again in the voltage standard. The actual difference that has resulted is perhaps best indicated in referring to the old 16-candle-power lamp. The old 16-candle-power, 50-watt lamp, having a rating of 3.1 watts per candle, under the present rating has become 16.83 candles, with the watts per candle-power efficiency of 2.97. This, interpreted in duration of service life, which is most sensitive to these changes, represents under equivalent conditions, assuming there were no improvement or progress in the actual manufacture of the lamp, a reduction in its life to 86 per cent of its former value under previous ratings, giving, however, a lamp of 2.97 watts per candle efficiency instead of 3.1.

Another effect of the change in the volt units, which is mentioned in the report, deserves perhaps a little consideration. This is the fact that, due to the change in volt units, the watt or unit of power has been increased by 0.16 per cent. This is a small quantity, which it is difficult to measure with commercial instruments. The allowable limit of error of watt-hour meters is much larger than this amount. The fact remains, however, that there has been an actual change in the size of the unit in which the output of all central stations is measured.

Now when the enormous figures into which the gross revenue of our central stations runs are considered, it will be seen that these changes in our fundamental standards have represented actual reductions in the revenue of the electric-lighting industry, in this country alone, of several hundred thousand dollars. That is the price which the industry in this country is paying, and paying cheerfully, for the sake of the attainment of international uniformity, international standardization, and a closer adherence to the theoretical relations between the practical sys-

tem and the centimeter-gram-second system of electrical units. But with these changes which have been indicated in Doctor Kennelly's report, the industry has been placed on a proper basis; because its fundamental measurements are now directly comparable with the other large branches of the lighting industry, the gas industry and ourselves; so that we are at last on the proper basis of being able to make direct international illuminating comparisons.

THE CHAIRMAN: We have a written discussion on this report by Doctor Sharp, of the Electric Testing Laboratory, which gives a valuable table showing the differences between the various standards, and some other data which may be of interest to those who want further details. As time passes, however, I will hand it to the stenographer so that it can be included in the report of the *Proceedings*.

DR. CLAYTON H. SHARP (contributed): In connection with the change in the value of the candle unit for the sake of establishing international uniformity which Dr. Kennelly notes in his report, it may be interesting to see the results of a practical test undertaken to discover how closely this international uniformity in candle-power has been attained.

As far back as 1903, the writer took a set of standardized incandescent lamps to the National Physical Laboratory in London, to the Laboratoire Central de l'Electricite in Paris and to the Physikalisch-Technische Reichsanstalt in Berlin. In each of these laboratories the candlepower of the lamps was measured. Results obtained at that time indicated a possibility of obtaining international uniformity by relatively slight changes.

Since 1903 numerous similar and more careful comparisons have been carried out by the Bureau of Standards, the results of which are noted in Dr. Kennelly's report. The matter of standards, therefore, being presumably put on a satisfactory basis, it was deemed interesting to repeat the operation of carrying a set of standardized lamps once more to these laboratories and to extend the comparison somewhat in view of more recent developments in lamp manufacture. This the writer did during the past summer.

Four lamps were taken of the drawn-wire tungsten type. At each point where a spire of the filament passed a support,

it was welded fast to the support, so that all loose or variable contacts in the lamp were avoided. These lamps, after having been seasoned, were standardized at two different voltages, (1) the voltage at which the color of the light was the same as the color of the carbon lamp as ordinarily operated, and (2) the voltage at which the color of the light was the same as that of the tungsten-filament lamp as ordinarily operated. The second voltages were substantially 50 per cent higher than the first. The reason for taking two voltages was that it was known that the color difference introduced in comparing a carbon with a tungsten lamp caused an error in photometry which differed with different individuals and which was by no means negligible. On account of this the Electrical Testing Laboratories had already adopted a series of tungsten lamp standards for regular work and it was desired to see how closely the value of these standards would be represented by the measurements obtained in foreign laboratories.

The results of the measurements are given in the following table. The values given by the Reichsanstalt are reduced to candle-power by multiplying them by the present nominal ratio of the Hefner to the candle, namely, 0.9.

	Lamp No. 3892 at 69.2 Volts		Lamp No. 3893 at 69.3 Volts		Lamp No. 3894 at 69.5 Volts		Lamp No. 3895 at 69.15 Volts		Averages	
	C.P.	Per Cent Dev.	C.P	Per Cent Dev.	C.P.	Per Cent Dev.	C.P.	Per Cent Dev.	C.P.	Per Cent Dev.
E. T. L.	6.0	—0.50	7.0	—0.28	8.5	—0.47	8.5	+0.47	7.5	—0.18
P. T. R.	6.075	+0.75	7.10	+1.14	8.65	+1.17	8.57	+1.18	7.60	+1.13
L. C. E.	6.0	—0.50	6.95	—1.00	8.5	—0.47	8.35	—1.30	7.45	—0.85
N. P. L.	6.06	—0.50	7.05	+0.43	8.565	+0.29	8.50	+0.47	7.54	+0.35
B. S.	6.0	—0.33	7.0	—0.28	8.5	—0.47	8.4	—0.71	7.48	—0.45
Mean	6.03		7.02		8.54		8.46		7.51	

	Lamp No. 3892 at 100.1 Volts		Lamp No. 3893 at 100.4 Volts		Lamp No. 3894 at 105.75 Volts		Lamp No. 3895 at 105.2 Volts		Averages		Ratio H.V.C.P. L.V.C.P.
	C.P.	Per Cent Dev.	C.P.	Per Cent Dev.	C.P.	Per Cent Dev.	C.P.	Per Cent Dev.	C.P.	Per Cent Dev.	
E. T. L.	31.0	0.	27.97	+0.25	42.0	+0.48	42.0	+0.48	35.74	+0.42	4.76
P. T. R.	31.6	+1.93	28.4	+1.79	42.9	+2.56	42.95	+2.75	36.45	+2.42	4.80
L. C. E.	30.5	—1.61	27.5	—1.43	40.7	—2.63	40.6	—2.86	34.82	—2.16	4.68
N. P. L.	30.9	—0.32	27.7	—0.72	41.75	—0.12	41.65	—0.36	35.50	—0.25	4.71
B. S.	30.8	—0.64	27.8	—0.36	41.6	—0.48	41.6	—0.48	35.45	—0.39	4.74
Mean	31.0		27.9		41.8		41.8		35.59		4.74

It will be seen that the various laboratories are in close agreement in their evaluation of these lamps as far as their determination at the ordinary color of carbon lamps is concerned. The greatest deviation from the mean is shown by the Reichsanstalt, namely, 1.1 per cent, which is not a surprising deviation in view of the fact that the Reichsanstalt measurements are all carried back to the Hefner lamp itself, whereas in the case of the other laboratories, measurements are carried back to a series of standardized incandescent lamps. Therefore the 1.1 per cent may represent a variation of the Hefner lamp from its mean value at the particular time it was used in connection with the measurements in question. With respect to the other deviations it may be said that they are so small that they illustrate the extreme closeness with which the standards are kept and the great care with which the photometric measurements were carried out. Such precision in international candle-power determinations was a thing not to be thought of only a few years ago.

With respect to the measurements of the lamps at the whiter color, the situation is not so good. Here considerable deviations come in which are evidently due to different individual valuations of lights of different color. The variations run from + 2.4 per cent to — 2.2 per cent. However, it is to be noted that in only three laboratories, namely, the National Physical Laboratory, the Bureau of Standards, and the Electrical Testing Laboratories, had special attention been given to the establishment of a well-defined line of white light standards and that among these laboratories the variations are less than the ordinary error of precision photometric work.

The above contribution, therefore, goes to show that international precision as well as precision in a single laboratory has been established in photometric measurements, and to emphasize the fact that a series of standards on one color only will not do. Different series of standards are required in precision work in order that the color of the standard may not differ too much from the color of the source of light which is under measurement.

The Chairman: Is there any further discussion? If not, I will call for the last paper of this session, "The Proper Lamp for a Circuit," by Mr. R. E. Campbell and Mr. M. D. Cooper, Cleveland, Ohio.

Mr. Cooper will present the paper.

THE PROPER LAMP FOR A CIRCUIT

In beginning this paper, permit the authors to acknowledge their indebtedness to those central stations that so kindly allowed the personal investigation of the line-voltage conditions on their circuits.

The purpose of the paper is to discuss briefly, from the standpoint of the central station, some of the factors which enter into the selection of the proper incandescent lamp for operation under given conditions.

The most important function of the central station is to obtain a profitable income by furnishing an economical and satisfactory light to its customers. In general it may be said that from the customer's viewpoint, it is possible to bring about a more economical production of light. Furthermore, the accomplishment of this will result in a greater profit to the central station, since the added income will more than counterbalance the slight increase in operating cost. For this reason the financial success of the electric lighting industry depends in a large measure upon the intelligent use of the incandescent lamp as a translating device. Therefore, the importance of supplying the customer with a lamp which is suited to his individual requirements will be appreciated when the competition of other illuminants is brought to mind.

In order to give a clear idea of what is meant by the proper lamp for a circuit, let it be defined as such a lamp as would produce:

1. Desired intensity of illumination,
2. Proper quality of light,
3. Minimum fluctuation of intensity,
4. Maximum economy.

Since the desired intensity of illumination and the proper quality of light have been so fully and ably discussed by others in previous papers, let us confine our attention to the remaining two items, the minimum fluctuation of intensity and the maximum economy in delivering light.

It is evident that in the main the effort to secure the most economical service from a lamp is principally a question of the efficiency at which it is to be operated. For any given lamp of

known voltage rating, the efficiency is governed by the pressure at which the current is supplied to it. Therefore, the problem of maximum economy is solved by maintaining the correct relation between lamp voltage and line voltage.

Since maximum economy depends on the line voltage and since fluctuation of intensity is governed by variation of voltage, we may say that the question of the proper lamp for a circuit can be referred to the value and variations of this one quantity —voltage. But the voltage at which energy is supplied to the customer is dependent upon the conditions surrounding plant operation, the transmission of energy and the translation of this energy into its final form—light.

Therefore, the selection of the proper lamp for a circuit depends upon the conditions surrounding:

1. Plant operation,
2. Transmission of energy,
3. Translation of energy into light.

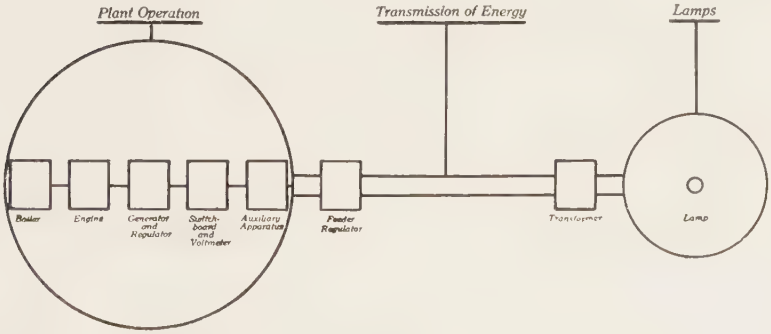


Fig. 1. Some of the Factors Entering Into Proper Lamp Operation

CONDITIONS SURROUNDING PLANT OPERATION

It is realized that the resources available for investigation of voltage discrepancies and application of the necessary remedies vary almost in proportion to the size of the central station. Recognizing this to be true, the authors gave particular attention in visiting central stations to those supplying a population of from 1500 to 15,000.

In considering the effect of plant operation on the voltage, the first element is naturally the prime mover. The steam

turbine, reciprocating engine, water turbine and gas engine are all designed to give fairly constant speed over a considerable range of load. The low speed reciprocating engine belted to a high speed generator is very likely to produce a cyclic fluctuation in voltage. No criterion for the amount of this fluctuation can be given, however, since it depends to a large extent upon the speed and size of the flywheel. In one plant which was visited a variation of this kind was encountered, which amounted to 4 volts on a 120-volt circuit. The condition noted above may be considerably aggravated by a loose belt connecting the prime mover and the generator.

The second element to be considered is the generator. The effect of power-factor on the increase in size of generator need not be discussed, since it does not affect the voltage at the terminals of the machine as long as the exciter is of sufficient capacity to supply the additional field current required.

It is a well known fact that the old style compound-wound alternators give much better inherent voltage regulation than the modern alternators. The tendency in the design of alternators, at the present time, is to neglect inherent voltage regulation, since much closer regulation can be secured by the use of more easily controlled auxiliary apparatus.

There are a number of forms of automatic generator voltage regulators on the market, but the one in most general use is the Tirrill type. An automatic voltage regulator can be depended upon to keep the voltage at a constant value at some designated point on the circuits, which may or may not be the bus-bars. One or two of the plants visited are utilizing the regulator on the switchboard to keep the voltage at a constant value at the center of distribution by leading pressure wires back to the switchboard. In the majority of cases, however, the point of regulation is at the station bus-bars.

On account of the initial cost of regulating apparatus, a great many of the smaller central stations hesitate to install a regulator. This is evidenced by the fact that only 25 central stations out of the 82 visited, had any form of automatic generator voltage regulator. It is becoming generally conceded, however, that due to the better maintenance of voltage, the investment necessary is an expenditure warranted by the improvement in service and consequent greater satisfaction to the cus-

tomer. The returns on such an investment can be expressed in dollars and cents directly as well as in terms of "good will."

The next element to be considered is the switchboard and the necessary measuring instruments. Of the instruments on the switchboard, the one in which we are principally interested is the voltmeter. This instrument might properly be termed the "pulse" of the central station. By means of the voltmeter the station attendant is enabled to judge the condition and quality of service which is being rendered. Thus an error in this instrument is most vital and is detrimental to satisfactory service. The switchboard voltmeter is used in both the indicating and recording types. Of the two types, perhaps the one to be preferred is the indicating type, due to its greater accuracy. But if possible a recording voltmeter should also be used, since it obviates any uncertainty as to what conditions prevailed at the time when complaint may have been caused by dim light.

In each plant visited, the switchboard voltmeters were checked against an accurate portable standard. Of the voltmeters so checked, 18 were found to be accurate within one volt, 51 were found to be reading higher than the actual voltage of the circuit to which they were attached and 26 were found to be reading low. The errors ranged from 1 to 10 volts as shown in Table No. 1.

TABLE NO. 1

Error of Voltmeter	Reading High	Reading Low
Accurate, 18		
1 Volt	2	3
1.5 Volts	4	. .
2 Volts	11	8
2.5 Volts	2	1
3 Volts	11	6
3.5 Volts	2	2
4 Volts	8	2
4.5 Volts	. .	1
5 Volts	7	1
5.5 Volts	. .	1
6 Volts	2	. .
7 Volts	1	1
10 Volts	1	. .
Totals,	51	26

A voltmeter which reads high causes a loss in revenue due to decreased wattage. It will also cause more complaints on service than one reading low, due to the fact that the lamps on the circuits are burning at a lower candle-power and a lower efficiency than that at which they are intended to burn. The maximum error encountered in this direction was 10 volts. The use of this voltmeter in setting the line voltage would be equivalent in the decrease of voltage to that which would be obtained by the transmission of 10 kilowatts at 220 volts over one mile of No. 16 copper bell wire.

If the amount of the instrument error is known, it becomes a very simple matter to allow for this in setting the marker which is usually provided on switchboard voltmeters.

The causes for instrument error are too well known to require our consideration in this paper, but it might be well to mention that alternating-current voltmeters are more apt to read high than low. That these errors are accumulative would seem to make periodic calibration of the switchboard voltmeters advisable. It is a fact of observation that in the smaller central stations less attention is paid to the calibration of instruments and for this reason their voltmeters are more likely to be inaccurate.

Wherever voltages of 1100 or 2200 volts are to be measured, it becomes necessary from the standpoint of both safety and accuracy, to make use of a potential transformer. These transformers are usually designed with a capacity of about 50 watts, and any overloading produces just such an effect as would be noticed in any other transformer which is loaded over its normal rated capacity. In other words, the voltage delivered at the terminals would be lower than under normal operating conditions. This has the effect of making the switchboard voltmeter which is connected to the instrument transformer read lower than it should. In a few stations the pilot lamps on the switchboard were found to be connected to the instrument transformer, thus causing an error of from 2 to 4 volts.

The last element to be considered in station operation is such apparatus as balancer sets and constant-current transformers. Due to the fact that continuous current finds its greatest application in the business districts of large cities where especial care is taken to secure proper balance, very little need be said concerning the balancer set.

The following is an interesting method of regulating a 3-wire circuit, which fulfills the required conditions. This scheme prescribes the use of a 220-volt generator and a balancer set—one automatic regulator being placed across the 220-volt busses and another regulator across one side of the balancer set, whose field coils are cross-connected. This method would find special application where an intermittent heavy load cannot be divided between both sides of the line.

Another form of auxiliary apparatus which has an effect on voltage regulation is the machinery used in supplying constant-current circuits. The principal trouble would be encountered when only one of these regulators is used on a 3-phase circuit. Their power-factor is so low that they cause considerable inductive drop on the one phase, thus distorting the normal condition of balance. An example of this was encountered in which the voltage on the three phases were equal without the regulator, but with the regulator, one phase measured three volts lower than the other two. This voltage drop would not cause as great a reduction in revenue, however, as would be the case if the voltage were low on all three phases.

CONDITIONS SURROUNDING THE TRANSMISSION OF ENERGY

The transmission of energy from the central station to the lamp socket is a very important step to be considered in placing the proper lamp on the circuit. It is in this step that the greatest voltage losses occur.

The usual designs of feeder systems aim to take care of the voltage drop within 2 per cent. It is realized, however, that in a commercial installation which must supply various classes of load, this condition is seldom attained.

As sometimes happens in small cities, the feeders which supply the business section also supply some of the residence section. It is obvious that the maintenance of a uniform voltage over the entire system—where the peaks of the business-lighting and residence-lighting loads do not coincide—would be practically an impossibility without suitable feeder regulators, regardless of the uniformity of the station voltage.

Automatic feeder regulators are made in a number of forms, as are also hand and motor-operated regulators. The use of a

regulator will often reduce the total expense necessary to maintain proper voltage regulation. This, of course, depends almost entirely upon the amount of load and distance of transmission. Only the largest central stations visited were found to have feeder regulators installed.

On 3-phase distributing systems it was found that in many of the smaller cities where the power load is almost all concentrated down town, the three phases are led to a center of distribution. From this center 3-phase power circuits are distributed and single-phase lighting circuits are taken off to various parts of the town. This works out very well as long as the power load and the lighting load do not overlap. At certain seasons of the year, however, they do overlap to a considerable extent and the low power-factor incident to the use of lightly loaded motors introduces a considerable primary drop, which would not otherwise occur.

At this point it may be well to give a summary of the transmission systems in general use. The following classification (Table No. 2) of the 82 plants visited shows the fact that the 3-phase, 2200-volt distribution system has found considerable favor among central station managers.

TABLE NO. 2

A. C.	2200 V.	1100 V.	220 V.	110 V.
Three-phase	33	6	..	..
Two-phase	10	4	..	..
Single-phase	10	10	..	..
D. C.				
Three-wire	..	.	6	.
Two-wire	..	.	4	4

The numbers in the above table total 87. This is due to the fact that in some of the cities visited both alternating and continuous current are available.

The transformer is another important consideration in supplying energy to the lamp at its rated voltage. It has been found that unless especial attention is given to the loading of transformers there is a tendency to overload them. This is in a large measure due to the rapid growth of the electric industry. Customers are being continually added to the transformers already

in service, with the result that they soon become considerably overloaded.

In selecting transformers for lighting loads, the regulation from no load to full load is a very essential point to consider. This is because the drop in a transformer is in addition to that in the feeder and the variations in generator voltage. Even

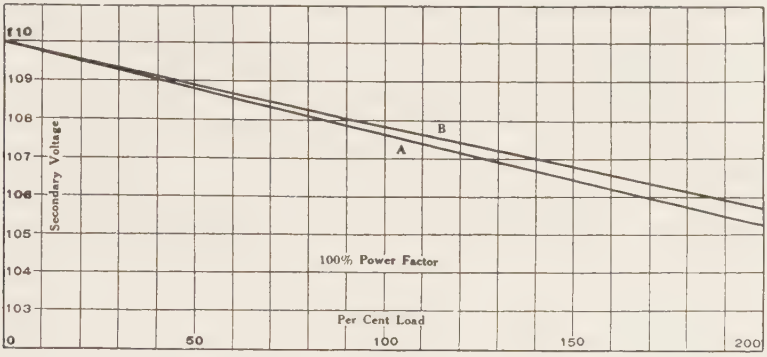


Fig. 2. Regulation of 5-Kva. Lighting Transformers 100 Per Cent Power-Factor

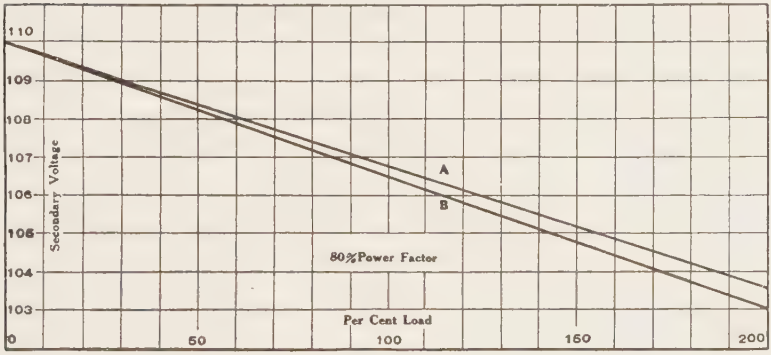


Fig. 3. Regulation of 5-Kva. Lighting Transformers 80 Per Cent Power-Factor

when the drop in the generator and feeder is compensated for at the switchboard, by hand or automatic regulation, it is impossible to keep the voltage at a uniform value all over the lines due to the different loading conditions on each transformer.

Figures 2 and 3 show the results of regulation tests at 100 per cent and 80 per cent power-factor on two different makes of transformers, 5-kva. capacity each—primary voltage 1100 and secondary voltage 110. These tests were performed in a university laboratory.

The effect of low power-factor on the regulation of a transformer is to increase still further the voltage drop. An 80 per cent power-factor will cause a drop from 4 to 5 per cent at full load. Added to this transformer drop is the secondary line loss and the loss in the customer's premises between the service switch and the lamp socket.

Fairness to the central station, however, will not permit of directly charging against the central station all this voltage loss which occurs between the service switch and the lamp socket, due either to unbalancing on the consumer's premises or insufficient copper. However, inasmuch as this affects the service given to the customer, some supervision of new installations on the part of the central station seems to be advisable.

In taking voltage readings on the lines of the central stations visited, an effort was made to obtain some data relative to the average secondary drop. An approximation of this voltage drop was arrived at by taking a reading at the nearest available point to the transformer and successive readings on the same secondary leads to the end of the line. Under average conditions, this should not amount to more than 2 per cent. However, in but few cases was this found to be actually attained—the average secondary drop being from 4 to 5 per cent. This indicates the fact that the secondary lines were, in the majority of cases, overloaded. Such a voltage loss still further decreases the value of the service to the customer and the available revenue to the central station.

In addition to the secondary drop, there is a voltage drop on the customer's premises, between the service switch and the lamp socket. The average maximum drop in this case was found to be about 2 per cent.

Effect of Voltage Loss on Revenue

The large majority of incandescent lamps are intended for operation on constant-potential circuits. Therefore, a lamp gives its rated candle-power and watts only when operated on a circuit

of a voltage equal to the rated voltage of the lamp. If the circuit voltage is less than the rated lamp voltage, the candle-power and watts are decreased. If the circuit voltage is greater than the rated lamp voltage, the candle-power and watts are increased. The curves shown in Figures 4 and 5 give the per cent watts and per cent candle-power which will be obtained at various voltages from tungsten-filament lamps rated at 108, 110, 112, 114 and 116 volts.

Some very striking figures can be given as to the effect on the revenue to the central station of maintaining the proper voltage at the lamp. Assume that out of $400,000,000 income to the central stations in the United States, $275,000,000 was the amount paid for lighting. If the voltage drop in each station could be reduced 2 per cent, the increase in revenue would be 4 per cent, or $11,000,000.

The following table (No. 3), based on the curve for a 110-volt tungsten-filament lamp as shown in Figure 4, gives the increase in revenue which can be obtained from the circuits by decreasing the drop over all the lines. Assume a connected lamp load of 50 kilowatts operating at an average of 6 volts under the rated lamp voltage. By decreasing the voltage drop 4 volts, the increase in revenue to the central station at 9-cent energy would be $273.85 per 1000 hours of operation.

TABLE NO. 3

Kw. Load of Lamps in Service	Gain in Revenue to Central Station per 1000 Hours, by Decreasing Voltage Drop					
	2 Volts	4 Volts	6 Volts	8 Volts	10 Volts	12 Volts
50	$ 14.80	$ 30.35	$ 46.65	$ 63.75	$ 81.85	$100.90
100	29.60	60.70	93.30	127.50	163.70	201.80
150	44.40	91.05	139.95	191.25	245.55	302.70
200	59.20	121.40	186.60	255.00	327.40	403.60
250	74.00	151.75	233.25	318.75	409.25	504.50
300	88.80	182.10	279.90	382.50	491.10	605.40
350	103.60	212.45	326.55	446.25	572.95	706.30
400	118.40	242.80	373.20	510.00	654.80	807.20
450	133.20	273.15	419.85	573.75	736.65	908.10
500	148.00	303.50	466.50	637.50	818.50	1009.00

This table has been figured on the basis of 1 cent per kilowatt. The gain in dollars can be found by multiplying the above figures by any given energy rate.

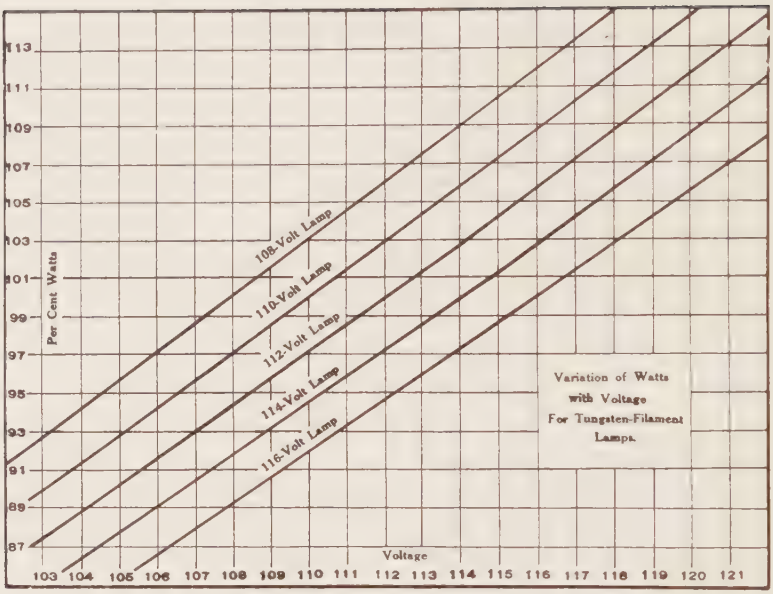


FIG. 4. PER CENT WATTS FOR VARIOUS VOLTAGES OBTAINED FROM TUNGSTEN-FILAMENT LAMPS

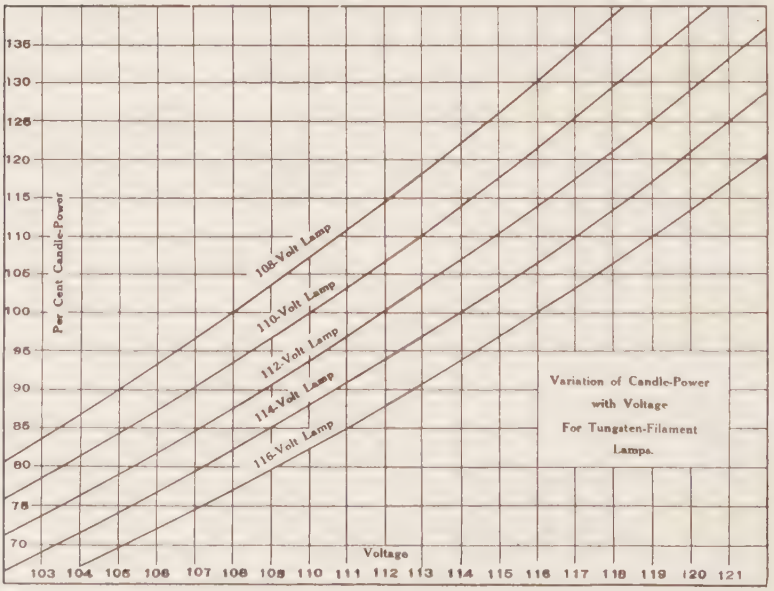


FIG. 5. PER CENT CANDLE-POWER FOR VARIOUS VOLTAGES OBTAINED FROM TUNGSTEN-FILAMENT LAMPS

In Table No. 4, based on the curve for a 110-volt tungsten-filament lamp as shown in Figure 5, is given the per cent increase in candle-power which would result from the decrease in voltage drop. A comparison of Table No. 3 with Table No. 4 will show the increase in service relative to the increase in revenue to the central station.

TABLE NO. 4

Gain in Per Cent Candle-power to Consumer by Decreasing Voltage Drop.					
2 Volts	4 Volts	6 Volts	8 Volts	10 Volts	12 Volts
7.0	14.6	22.9	32.0	41.7	52.6

We have considered the various factors in central station operation which involve the generation, control and transmission of energy for the purpose of lighting. We have discussed the conditions, favorable and unfavorable, which affect the transmission of energy at the proper voltage.

At the beginning of the paper it was stated that the efficiency of a lamp is governed by the voltage at which current is supplied thereto. It is realized that the conditions which have been discussed affecting the line voltage are not so much a matter of neglect as of the difficulties due in many cases to limited finances. It remains to show, then, that a satisfactory service to the customer can be approximated, although these conditions may not be altered at once.

It is assumed that each central station is making every possible effort to keep pace with the rapid progress which is being made in operating conditions and, consequently, improvement in the service to the customer. The final view of the relation of operating conditions to the production of light is all that remains to be considered.

TRANSLATION OF ENERGY INTO LIGHT

The relation of operating conditions to the production of light may be stated as the relation between line voltage and lamp voltage.

Line Voltage and Lamp Voltage

In any electrical supply system the voltage supplied to the customer's premises is bound to vary with the distance of transmission and with the time of day. In making a strictly scientific selection of lamps any particular customer is concerned only with the variations of voltage with time. In selecting a lamp for use on a circuit of fluctuating voltage, various fundamental criteria may be used; *i. e.,* the lamp voltage could be selected so that the average of the candle-power values given at all times would be the same as if the lamp were burned continuously at its rated voltage; similarly, the wattage consumption or the efficiency might be adjusted for correct average values; or the lamp voltages could be so chosen that the life of the lamp would be the same as when burned continuously at rated voltage. Of the above mentioned factors—candle-power, wattage, efficiency and life—the last will be found to vary more with changes of voltage than any of the others. Hence, if a lamp is so selected that a proper life is obtained, approximately correct values of the candle-power, wattage and efficiency will also be obtained.

It seems to be commonly accepted as a fact, that the average voltage of a circuit during lighting hours is the proper voltage rating for the lamps to be used thereon. Judged from the equivalent life criterion for lamp selection, such is not strictly the case. If a lamp is burned half of the time at a given percentage below its normal voltage and half of the time at the same percentage above this normal value, it will be found that its life is decreased. The magnitude of the decrease will depend upon the difference between the burning voltages and the rated voltage. The reason for this is that in a given period of burning at overvoltage, more of the inherent life of the lamp is consumed than is recovered when burning for an equal length of time at a corresponding amount undervoltage—the net effect being shorter life.

It is evident, therefore, that if during lighting hours the voltage of a circuit fluctuates above and below an average value, the theoretical proper lamp voltage is slightly higher than this average voltage, and the greater the fluctuations, the greater should be the difference between average voltage and lamp voltage.

Mathematical analysis shows that it is only on circuits which have excessive voltage fluctuations (such as heavily loaded com-

bination power and lighting circuits, railway circuits, etc.) that the above difference will amount to enough to warrant serious consideration. As a general rule it may be stated that the difference between the scientifically correct lamp voltage and the average line voltage during lighting hours will not amount to even one volt unless the circuit voltage fluctuates more than 6 per cent above and below this average value.

A central station, in selecting the proper lamp to use on its system, is confronted with a more complicated problem than is any individual customer in selecting the proper lamp for his premises, since the station has to consider the variation of voltage both with time and with distance. In some systems the variations with distance are so great that it is hardly feasible to use one voltage of lamp for the entire system. In such cases the area supplied is divided up into districts and a different voltage lamp supplied to each district. Whether such a practise is commendable will depend entirely upon local conditions. In small cities, where the station employees are acquainted more or less intimately with all the customers and know the location of their premises, but little trouble would be encountered in filling their orders for lamps. In larger cities, however, where acquaintances are not so intimate, such a lamp renewal system would be complicated and expensive. Of course, it is always desirable to give the customer a lamp which is adapted to his individual installation in order to insure the best possible service. In the larger cities, the resources of the central station would more often be such that the apparatus required to maintain a reasonably uniform voltage over the whole system could be purchased and installed.

Example of Determination of Proper Lamp Voltage

As a general summary of the preceding considerations may be related an investigation recently made in a city of 130,000 people for the purpose of standardizing the lamp voltage. The business district of this city was supplied with 220-volt, 3-wire, continuous-current and the remainder of the city with 2300—115-volt alternating-current.

At times corresponding to the lighting peak, a large number of voltage readings were taken in the continuous-current district, particular pains being taken to secure the voltage on both sides

of the line at each place tested. These data showed bad conditions of unbalancing—there being in some cases as much as 10 volts difference between the two sides of the line. Since the station was planning to put its continuous-current circuits underground, it was assumed that in the change the conditions of unbalance would be eliminated. The average voltage of the two sides of the line was therefore recorded for each location tested. After covering the whole continuous-current district, it was found that the average voltage was 119.5 volts. The voltage was found to vary considerably with distance—from 115 at the outskirts of the district to 125 at points near the plant. Ordinarily under conditions like this, the best recommendation would be to use lamps of different voltages for different parts of the circuit. In view of the fact that when the lines are put underground, they will at the same time be considerably reinforced, it was assumed that the variations of voltage with distance will be materially decreased; and also, since it was very much desired to use the same voltage of lamp throughout the area served, it was recommended that 120-volt lamps should be used universally in the continuous-current district; 120-volt lamps were recommended, rather than 119-volt, on account of the variations of the voltage, the 0.5-volt difference between lamp voltage and average line voltage being allowed in conformance with the preceding discussion.

Under the conditions prevailing, the customers near the station would be getting an increased candle-power and a decreased life from their lamps, and the customers at the ends of the lines would be getting a decreased candle-power and an increased life, but the average conditions for the whole district would be as nearly correct as possible.

The voltage conditions on the alternating-current system of this station had been greatly improved by the recent installation of automatic induction regulators on each of the ten feeders. These regulators had been carefully placed at the center of load on each feeder and were set to maintain constant voltage at these centers of distribution. Recording voltmeters were placed at these centers and during the lighting hours a number of voltage readings were secured at the extreme ends of the lines supplied from each center. Comparison of these readings with the indications of the recording voltmeters gave data as to the maximum drop from center of distribution to the extreme load. Consider-

ation will show that the average of the voltage drops from a center of distribution to all of the individual loads will be more than half of the drop from the center of distribution to the farthest load. A theoretical calculation showed that the former will, in most cases, be approximately 70 per cent of the latter. Taking 70 per cent of the average maximum drop on each feeder, and adding this to the desired lamp voltage, the voltage is obtained for which the feeder regulator should be set.

The voltage readings and determinations of line drop were all made during the time of heavy lighting load, *i. e.,* between 5 and 10 P. M. Of course, some lamps are in use after this period, and the voltage is liable to be higher than during the early part of the evening, but the number of lamps which are in use after 10 P. M. will be so small compared with the number in use during the early evening that the voltage conditions prevailing after 10 P. M. can be well neglected in making any general selection of lamps.

Revenue and Service

As stated at the beginning of the paper, the object of the central station is:

1 To furnish a satisfactory and economical light to its customers.

2 To furnish this light at a profit to the station.

Any procedure which will lead to the production of a more satisfactory or more economical light and at the same time will result in a greater profit to the central station will therefore be of general economic benefit.

Tables 1, 2, 3 and 4, in the appendix, show what economic results will be obtained by burning some of the common types of lamps at various voltages. These tables show, for energy rates of 6, 9 and 12 cents per kw-hr., the increase of income to the station for various percentages of normal lamp voltage ranging from 96 per cent to 108 per cent. The total cost (energy cost plus lamp cost) to the customer is also shown, together with the cost per unit of light (1000 cp-hrs.). The bold face figures in the unit cost columns indicate the percentage of normal voltage at which the customer will secure light for the minimum total expenditure per unit.

An inspection of these columns will show that there is a considerable range of operation both above and below the point

of maximum economy over which the unit cost of light changes by an almost negligible amount. Take for example the 40-watt tungsten-filament lamp operating on 6-cent energy. The table shows that if the lamp is burned at 1 per cent undervoltage, the maximum economy will result, the cost per 1000 cp-hrs. in this case being 10.24 cents. It will be noticed that over a range of 3 per cent in voltage on both sides of this point, the unit cost to the customer increases by only 1 per cent. Corresponding to operation at 3 per cent below the point of maximum economy, the revenue to the station is $2.204; at the point of maximum economy it is $2.314; and at 3 per cent above it is $2.422, or the relative percentages are 95.2 per cent, 100 per cent and 104.5 per cent.

Suppose that a central station were so operating that, due to line drop or other voltage losses, the lamps were operating at 3 per cent below the point of maximum economy.

By eliminating a portion of the voltage losses or by arbitrarily raising the station voltage 3 per cent in order to counterbalance these losses, the central station could increase its revenue 5 per cent, furnish 12 per cent more light, and improve the economy of light production by 1 per cent. By eliminating still more of the losses and thus supplying 6 per cent more than the original voltage, the revenue could be increased 10 per cent. At the same time, the customer would secure 24 per cent more light at no greater cost per unit.

Nothing has yet been said about lamp renewals, since in nearly all cases tungsten-filament lamps are not given as free renewals. Even with metallized-carbon-filament lamps the large majority of central stations do not follow a free renewal policy.

Viewed only from the standpoint of income to the central station, there is no limit to the increase of voltage which will prove profitable, provided the customer supplies his own lamps. From the point of the customer, however, the increase in renewal expense makes it inadvisable for the central station to increase its voltage beyond the point at which the lamps will still give a satisfactory life.

The question as to what lamp life will prove satisfactory depends largely upon the customer. In most cases he is willing to purchase one tungsten-filament lamp every 6 to 9 months for each of the sockets equipped therewith, but a shorter life

than this would possibly result in complaints. When it is considered that in 1000 hours operation a 60-watt, tungsten-filament lamp will consume 10 times its list price cost in energy (assuming 9 cents per kilowatt-hour) and in the same period a 60-watt, metallized-filament lamp will consume 27 times its list price cost in energy, it will be seen that the question of the cost of energy for the light delivered is of relatively far greater importance than cost of lamp renewals.

Under a free renewal policy, the voltage increase which would prove profitable to the central station is limited, due to the fact that beyond a certain point the renewal expense increases faster than the total income.

Table 4 (appendix) shows some figures on the economics of the gem or metallized-filament lamp. Since the 60-watt size is in most general use, it was selected as the basis for the table. The table shows the total revenue from the sale of energy; the renewal expense; the difference of these—the net revenue; their sum—the total expense of producing light,* and the total cost of light per unit. This table shows that the point of maximum economy to the customer comes at a higher percentage of normal voltage than in the case of the tungsten-filament lamp. In fact, it is so high that actual operation of the lamps at this point would be commercially impracticable, due to the very short life which would result. It will be noted that the point of maximum net revenue is within the range of commercial attainment.

It is interesting to note in passing that under normal operating conditions, the unit cost of producing light with tungsten-filament lamps is slightly less than half of the cost of production with a gem lamp of equal wattage.

As regards the relation between the rated voltage of lamps and the voltage at which it is economical and profitable to burn them, a consideration of the tables will show that in general the latter is the higher. In a great many cases it is true that it is more profitable to the central station and gives the customer more for his money to burn the lamps over the rated lamp voltage rather than under the rated lamp voltage.

The marvelous growth of the electric lighting industry has made it almost impossible for the management of a small central

*This is really the total cost to the customer, since even under a free renewal policy the customer actually does pay a certain renewal cost.

station to employ in plant operation all of the improved devices which are used to secure maximum economy and better regulation. By making a careful study of the conditions which actually exist in present installations, however, and by selecting the proper lamp to fit these conditions, it is possible to give a very much improved service to the customer. It should be borne in mind that good service is an asset and its maintenance means increased favor with the customer, more new business, an increase of revenue and hence greater profits.

APPENDIX

The general problem of the economical production of illumination is not quite the same as the problem of the economical production of light, for conditions can be readily imagined under which light might be produced very uneconomically, and yet the resultant illumination be secured with a minimum of total expenditure in fixed and operating costs. As instances might be cited cases where architectural conditions necessitate an excessive quantity of light, yet the fixed charges which would be added as a result of bettering the architectural conditions would entirely outweigh the decrease in operating expense resulting from the saving in quantity of light required for a given illumination. In another case it might be that the expense of changing wiring and increasing the number of outlets or of increasing the size of reflectors or glassware to accommodate larger lighting units would not be warranted, even in the face of a high renewal expense due to burning lamps at a voltage higher than their rating in order to secure a greater quantity of light per lamp.

Recognizing, therefore, that the economical production of illumination for any room, building, or area may be, and in many cases is, affected by local conditions which must be treated individually, it would be difficult to give a general solution to the problem.

The average total cost per unit of light produced by means of incandescent lamps may be considered as made up of two elements, the cost of energy and the cost of renewals.

The wattage and candle-power of a given type of lamp, which determine the energy cost per unit of light produced, depend not only upon the initial efficiency, but also upon the variation of wattage, candle-power and efficiency throughout life. The average life can be approximately determined in terms of the initial efficiency of the lamp, but the actual renewal expense per unit of light produced depends upon the candle-power produced, and hence upon the variation of candle-power throughout life as well as upon the initial efficiency. The closeness with which the lamps adhere to their average life will also have an effect upon the renewal expense per unit of light produced.

From the point of the user of light it is thus seen that the factors which govern the cost of light per unit produced and the variation of the unit cost are as follows:

1. The cost of energy.
2. The rate system under which energy is purchased.
3. The cost of the lamp.
4. The arrangement under which lamps are secured by the user.
5. The initial efficiency of the lamp.
6. The minimum percentage of initial candle-power to which the lamps are allowed to decrease.
7. The variation of candle-power and wattage during life.
8. The uniformity in total life of a number of the lamps.

Regardless of the relative effect among themselves of items 7 and 8, "Variation of candle-power and wattage" and "Uniformity of life," their combined effect on the cost of light is governed by the two items, 5 and 6, "initial efficiency," and so-called "smashing point." Regardless of whether it can be shown to be economical to throw a lamp away before it burns out, it must be recognized that, particularly in the case of tungsten-filament lamps, nearly all lamps are left on circuit until they actually burn out. As far as the lamp is concerned, the efficiency is therefore the primary factor which controls the cost of the service rendered by it.

Assuming for the moment a uniform rate per kilowatt-hour for energy, a fixed price per lamp, and a uniform smashing point (which in commercial installations, corresponds to the total life of the lamps), an increase of efficiency (decrease of watts per candle) will bring about a decrease in the energy element of the unit cost of light produced and an increase in the renewal element. On the other hand, a decrease of efficiency will bring about an increase of the energy element and a decrease of the renewal element. As these opposite variations of the two elements of cost are not necessarily of equal magnitude for a given change of efficiency, it is evident that the problem of securing the most economical production of light (as distinguished from the production of illumination) is mainly a question of the efficiency at which the lamp is to be operated.

Since we have assumed a uniform energy rate and a fixed price of lamps, this statement applies directly in the case of a user of light only when this user buys his own lamps and buys or generates energy at a uniform cost per kilowatt-hour. Considered from a general economic point of view, however, the state-

ment is universally true, for notwithstanding rate systems and renewal policies, there is sure to be some definite and nearly constant cost per unit of energy, and some definite and fixed cost of lamp. If a customer of a central station secures free renewals, he would on first thought consider his cost of lamp to be zero, but if all such customers adjusted the operating efficiency of their lamps to some high value to correspond to this assumption, they would soon find that the central station would so alter its system of charging that the new conditions of increased renewal expense would be adequately covered. Even with free renewals, it is therefore evident that some definite price of lamp should be considered by the customer. A user of light who secures his energy at a contract price of so much candle-power per month might be inclined to consider the energy element of his total cost of light as fixed and invariable and correspondingly to adjust the efficiency of his lamps to some low value to correspond with this assumption, but here again there would ultimately be a readjustment of charges to meet the altered conditions; hence this customer should consider some definite amount of energy expense per unit of light produced at any efficiency, or in other words, some definite kilowatt-hour rate corresponding closely to the actual cost of delivering energy to him.

To reduce the preceding general discussion to concrete figures, the following cost data is given for four common types of lamps—the 25, 40 and 60-watt tungsten-filament and the 60-watt metallized carbon-filament lamps. For the purpose in hand it is more convenient to speak of burning a lamp at some given percentage of its normal voltage rather than to speak of operation at various efficiencies. The tables show the cost of energy or income to the station, the total cost to the customer and the cost of light per unit as the burning voltage varies from 96 to 108 per cent of the normal rated voltage. On the assumption of free renewals of the metallized-filament lamp, figures are given showing the difference between cost of energy and renewal expense, which is equivalent to the net revenue to the station.

The depreciation of candle-power and wattage during life is considered in these tables and the renewal costs are computed in accordance with the conservative rating of 1000 hours life for the tungsten-filament and 700 hours for the metallized-filament lamp. Therefore the tables can be safely applied to conditions as they are found in practise.

TABLE NO. 1

25-WATT TUNGSTEN-FILAMENT LAMP

Average candle-power during life=87% of initial
Average wattage during life =97% of initial

% Line Voltage of Lamp Voltage	Initial Candle-power	Initial Watts	C-p-hrs. per 1000 hrs.	Kw-hrs. per 1000 hrs.	Income to Station per Lamp per 1000 hrs. @ 6 cents	@ 9 cents	@ 12 cents	Renewal Cost per 1000 hrs. List Price	Total Cost to Customer per Lamp per 1000 hrs. @ 6 cents	@ 9 cents	@ 12 cents	Total Cost to Customer per 1000 c-p-hrs. @ 6 cents	@ 9 cents	@ 12 cents
					Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents
96	16.4	23.4	14,310	22.72	136.3	204.4	272.7	28.4	164.7	232.8	301.1	**11.51**	16.26	21.04
97	17.1	23.8	14,860	23.08	138.5	207.7	277.0	32.8	171.3	240.5	309.8	11.52	16.19	20.84
98	17.7	24.2	15,440	23.47	140.9	211.2	281.7	37.8	178.7	249.0	319.5	11.57	16.13	20.69
99	18.4	24.6	16,020	23.86	143.1	214.8	286.2	43.5	186.6	258.3	329.7	11.65	**16.12**	20.58
100	19.1	25.0	16,610	24.24	145.5	218.2	291.0	50.0	195.5	268.2	341.0	11.77	16.14	20.53
101	19.8	25.4	17,240	24.63	147.8	221.7	295.6	57.4	205.2	279.1	353.0	11.90	16.19	**20.48**
102	20.5	25.8	17,860	25.02	150.1	225.2	300.3	65.6	215.7	290.8	365.9	12.07	16.28	20.53
103	21.1	26.2	18,500	25.40	152.5	228.6	305.0	75.2	227.6	303.8	380.2	12.30	16.42	20.56
104	22.0	26.6	19,170	25.78	154.9	232.1	309.7	85.9	240.6	318.0	395.6	12.55	16.59	20.63
105	22.9	27.0	19,870	26.21	157.3	235.9	314.5	98.1	255.4	334.0	412.6	12.85	16.81	20.77
106	23.6	27.4	20,570	26.60	159.6	239.4	319.2	112.1	271.7	351.5	431.3	13.20	17.08	20.97
107	24.5	27.8	21,290	27.00	162.0	244.0	324.0	126.9	288.9	370.9	450.9	13.55	17.41	21.17
108	25.3	28.3	22,030	27.40	164.4	246.6	328.8	144.5	308.9	391.1	473.3	14.02	17.75	21.48

TABLE NO. 2

40-WATT TUNGSTEN-FILAMENT LAMP

Average candle-power during life=87% of initial
Average wattage during life =98% of initial

% Line Voltage of Lamp Voltage	Initial Candle-power	Initial Watts	C-p-hrs. per 1000 hrs.	Kw-hrs. per 1000 hrs.	Income to Station per Lamp per 1000 hrs. @ 6 cents	@ 9 cents	@ 12 cents	Renewal Cost per 1000 hrs. List Price	Total Cost to Customer per Lamp per 1000 hrs. @ 6 cents	@ 9 cents	@ 12 cents	Total Cost to Customer per 1000 c p-hrs. @ 6 cents	@ 9 cents	@ 12 cents
					Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents
96	28.0	37.5	24,340	36.72	220.4	330.6	440.8	31.3	251.7	361.9	472.1	10.34	14.86	19.40
97	29.1	38.1	25,290	37.31	223.9	335.8	447.8	36.1	260.0	371.9	483.9	10.28	14.70	19.13
98	30.2	38.7	26,280	37.92	227.5	341.3	455.1	41.6	269.1	382.9	496.7	10.25	14.56	18.90
99	31.3	39.4	27,270	38.57	231.4	347.1	462.8	47.9	279.3	395.0	510.7	**10.24**	14.48	18.71
100	32.5	40.0	28,280	39.19	235.1	352.7	470.3	55.0	290.1	407.7	525.3	10.26	14.41	18.57
101	33.7	40.6	29,330	39.82	238.9	358.4	477.9	63.1	302.0	421.5	541.0	10.29	14.37	18.44
102	34.9	41.3	30,400	40.45	242.2	363.3	484.4	72.2	314.4	435.5	556.6	10.35	**14.33**	18.31
103	36.2	41.9	31,500	41.07	246.4	369.6	492.9	82.7	329.1	452.3	575.6	10.45	14.36	18.27
104	37.5	42.5	32,620	41.70	250.2	375.3	500.4	94.4	344.6	469.7	594.8	10.56	14.40	18.24
105	38.9	43.2	33,830	42.38	254.2	381.4	508.5	107.8	362.0	489.2	616.3	10.70	14.46	**18.22**
106	40.2	43.9	35,000	43.00	258.0	387.0	516.0	123.3	381.3	510.3	639.3	10.89	14.58	18.25
107	41.6	44.5	36,240	43.65	261.9	393.9	523.8	139.6	401.5	533.5	663.4	11.08	14.72	18.30
108	43.1	45.2	37,500	44.30	265.8	398.7	531.7	159.0	424.8	557.7	690.7	11.33	14.87	18.42

TABLE NO. 3

60-WATT TUNGSTEN-FILAMENT LAMP

Average candle-power during life=87% of initial
Average wattage during life =98% of initial

% Line Voltage of Lamp Voltage	Initial Candle-power	Initial Watts	C-p-hrs. per 1000 hrs.	Kw-hrs. per 1000 hrs.	Income to Station per Lamp per 1000 hrs. @ 6 cents	@ 9 cents	@ 12 cents	Renewal Cost per 1000 hrs. List Price	Total Cost to Customer per Lamp per 1000 hrs @ 6 cents	@ 9 cents	@ 12 cents	Total Cost to Customer per 1000 c-p-hrs. @ 6 cents	@ 9 cents	@ 12 cents
					Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents
96	43.7	56.2	38,060	55.10	313.7	470.6	627.4	42.7	356.4	513.3	670.1	9.37	13.48	17.61
97	45.4	57.1	39,520	55.96	318.8	478.2	637.6	49.2	368.0	527.4	686.8	9.32	13.34	17.38
98	47.2	58.1	41,060	56.93	324.1	486.2	648.2	56.7	380.8	542.9	704.9	9.28	13.22	17.17
99	49.0	59.0	42,600	57.86	329.3	494.0	658.7	65.2	394.5	559.2	723.9	**9.26**	13.13	16.99
100	50.8	60.0	44,180	58.80	334.8	502.2	669.6	75.0	409.8	577.2	744.6	9.28	13.06	16.85
101	52.7	61.0	45,830	59.74	340.3	510.4	680.6	86.0	426.3	596.4	766.6	9.30	13.02	16.73
102	54.6	61.9	47,500	60.68	345.7	518.5	691.4	98.6	444.3	617.1	790.0	9.35	**12.98**	16.63
103	56.6	62.9	49,230	61.60	351.0	526.5	702.0	112.7	463.7	639.2	814.7	9.42	**12.98**	16.55
104	58.6	63.9	51,000	62.56	356.4	534.6	712.8	128.9	485.3	663.5	841.7	9.52	13.01	16.51
105	60.6	64.9	52,800	63.54	361.8	542.7	723.6	147.0	508.8	689.7	870.6	9.63	13.06	**16.49**
106	62.9	65.8	54,700	64.53	367.3	551.0	734.7	168.1	535.4	719.1	902.8	9.79	13.14	16.50
107	65.1	66.8	56,630	65.51	372.9	559.4	745.8	190.4	563.3	749.8	936.2	9.94	13.24	16.53
108	67.4	67.8	58,600	66.48	378.4	567.6	756.8	216.7	595.1	784.3	973.5	10.15	13.38	16.60

TABLE NO. 4

60-WATT METALLIZED CARBON-FILAMENT LAMP

Average candle-power during life=83% of initial
Average wattage during life =96% of initial

% Line Voltage of Lamp Voltage	Initial Candle-power	Initial Watts	C-p hrs. per 1000 hrs.	Kw hrs. per 1000 hrs.	Income to Station per Lamp per 1000 hrs. @ 6 cents	@ 9 cents	@ 12 cents	Renewal Cost per 1000 hrs. List Price	Net Income to Station per Lamp per 1000 hrs. @ 6 cents	@ 9 cents	@ 12 cents	Total Cost to Customer per Lamp per 1000 hrs. @ 6 cents	@ 9 cents	@ 12 cents	Total Cost to Customer per 1000 c-p-hrs. @ 6 cents	@ 9 cents	@ 12 cents
					Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents
96	19.7	55.8	16,350	53.51	321.1	481.6	642.1	13.9	307.2	467.7	628.2	335.0	495.5	656.0	20.48	30.30	40.12
97	20.7	56.8	17,200	54.55	327.3	490.9	654.6	16.7	310.6	474.2	637.9	344.0	507.6	671.3	20.00	29.52	39.03
98	21.8	57.9	18,060	55.53	333.2	499.7	666.3	20.0	313.2	479.7	646.3	353.2	519.7	683.6	19.56	28.77	37.86
99	22.9	58.9	18,970	56.56	339.4	509.1	678.8	23.9	315.5	485.2	654.9	363.3	533.0	702.7	19.15	28.10	37.03
100	24.0	60.0	19,920	57.60	345 6	518.4	691.2	28.6	317.0	489.8	662.6	374.2	547.0	719.8	18.79	27.46	36.14
101	25.2	61.1	20,900	58.64	351.8	527.7	703.6	34.1	**317.7**	493.6	669.5	385.9	561.8	737.7	18.46	26.87	35.28
102	26.4	62.2	21,910	59.67	358.0	537.1	716.1	40.5	317.5	496.6	675.5	398.5	577.6	756.6	18.20	26.37	34.54
103	27.7	63.3	22,980	60.71	364.3	546.4	728.5	48.1	316.2	498.3	680.4	412.4	594.5	776.6	17.95	25.88	33.80
104	29.0	64.4	24,080	61.81	370.8	556.3	741.7	57.0	313.8	**499.3**	684.7	427.8	613.3	798.7	17.76	25.47	33.16
105	30.4	65.5	25,220	62.84	377.0	565.6	754.1	67.4	309.6	498.2	686.7	444.4	633.0	822.5	17.63	25.12	32.62
106	31.8	66.6	26,420	63.94	383.6	575.4	767.3	79.7	303.9	495.7	**687.6**	463.3	655.1	847.0	**17.54**	24.80	32.07
107	33.3	67.7	27,610	65.03	390.2	585.3	780.4	94.0	296.2	491.3	686.4	484.2	679.3	874.4	**17.54**	24.60	31.68
108	34.8	68.8	28,880	66.13	396.8	595.2	793.5	110.9	285.9	484.3	682.6	507.7	706.1	904.4	17 62	24.52	31.40
																Min. at 100% Volts	Min. at 111½% Volts

Central Station No.	Private or Municipal Plant	Service hrs.	Kw Capacity	Source of Power	Phases	Cycles	Voltage Pri. Sec.	Method of Regulation	Line Voltage During Lighting hrs. Max.	Min.	Avg.	Drop in % of Plant Voltage Max.	Avg.	Max. Unbalance	Lamp Voltage Tung'n Fila'nt	Metal'd Fila'nt	Station Voltmeter Volts High	Volts Low
1	Private	24	9000 3500	Steam	3	60	2300 115 0 250	Automatic	123. 130.	109 110	117. 120.	11 1 8 3	4.1 2.0	10-D. C.	113 120	113 120	O. K.	..
2	Private	24	150	Steam	2	60	1100 104	Hand	110.2	97.3	105.	13.1	6.3	....	110	110	..	3
3	Private	24	320	Steam	3	60	1100 115	Hand	118.2	109.5	112	7.2	5.1	1.5	115	115	1 5-2	.
4	Private	24	130	Steam	.	0	220 3-wire	Hand	115.5	108.0	111.	6.9	4 3	....	117	115	3	.
5	Private	12	200	Steam	1	60	2300 115	Hand	129.0	121 5	125.	6.5	4.0	....	125	120	O.K.-1	.
6	Private	24	500 150	Steam	3	60 0	2300 110 220	Automatic	121.0	106.0	117.	11.6	2.5	....	114	114	O.K.-3	..
7	Private	24	300	Steam	3	60	2300 115	Automatic	117.	105 1	112.	9 5	3.4	2.5	117	117	O K.-4	
8	Private	24	100	High Ten'n	3	60	2300 115	None	112.1	106.1	107.	7.0	6.1	....	114	112	3	
9	Private	24	150	Steam	.	0	250 3-wire	Hand	125 3	99.4	108.	12 2	4.4	Periodic 12	112	112	5	.
10	Municipal	24	125	Steam	2	60	2300 115	Hand	113.1	104 1	107	10 5	7 0	....	114	113	O.K.-4	
11	Private	24	150	Steam	1	60	1100 110	Hand	116.5	98.3	106.	15 5	8.6	....	112	110	4	2
12	Municipal	12	150	Steam	1	60	2200 110	Hand	113.2	102.	105.	8.2	5.5	..	112	112	2	
13	Private	24	275	Steam	1	60	2300 110	Automatic	122.0	112	116.	5 1	3.9	..	112	112		3
14	Municipal	24	200	Steam	2	60	2300 110	Hand	117 0	108 0	112.	7.7	4.5	....	112	112		1
15	Private	12	100	Steam		0	220 3-wire	Hand	235	170	196.	....	....	.	120	120	5	
16	Private	12	300	Steam	3	60	2300 110	Hand	115.5	100.	106.	15.9	10.4		106	106	..	1
17	Municipal	24	400	Steam	1 & 3	60	2300 110	Hand	111 0	103.	109.	6 4	3.6		115	115	. . .	4
18	Private	24	900	Steam	3	60	2300 110	Automatic	111.5	106.	109	7.0	4 4	..	112	112		3
19	Private	12	60	Steam	1	60	2300 110	Hand	115.9	104.	112.	12 6	5.5		117	115	...	5
20	Private	12	180	Steam	1	60	2300 115	Hand	106 9	99	103	11 6	7.2	.	110	110		3
21	Municipal	12	100	Steam	1	135	1100 104	Hand	112.5	106.8	109.	10.8	9.2	...	106	104		4
22	Private	24	40 400	Steam	2	60 0	2200 110 110	Hand	115 2	100.	106	13 8	8 8		114	112	3	
23	Private	24	125	Steam	3	60	2300 115	Hand	131 2	106 3	118.	14 7	5 4	6 5	114	112		7
24	Private	24	225	Steam	1	133	1100 100	Hand	100.5	98 4	106.	10 9	3.6	..	112	112	2-5	
25	Private	24	150	Steam	2	60	1100 110 104	Hand	108.0	100.3	104	7 4	3 7	.	108	106	4	2
26	Private	24	350	Steam	2	60	2200 110	Hand	113 2	106.	109	7.0	4.4	....	110	108	3	..

Central Station No.	Private or Municipal	Service hrs.	Kw. Capacity	Source of Power	Phases	Cycles	Voltage Pri. Sec.	Method of Regulation	Line Voltage During Lighting Hrs.			Drop in % of Plant Voltage		Max. Unbalance	Lamp Voltage		Station Voltmeter	
									Max.	Min.	Ave.	Max.	Ave.		Tung'n Fila'nt	Metal'd Fila'nt	Volts High	Volts Low
27	Municipal	24	210	Steam	..	0	250 3-wire	Hand	123.5	106.2	110.	12.9	10.5	4	127	123	5	....
28	Private	24	100	Steam	1	60	1100/110	Hand	110.2	102.0	106.	10.5	7.0	..	118	118	6	....
29	Municipal	24	150	Steam	1	60	2300/115	Automatic	116.3	102.1	111.	12.8	5.1	..	117	117	2	....
30	Private	24	150	Steam	..	0	125	Hand	123.3	100.2	112.	20.6	11.2	..	120	120	..	3.
31	Municipal	24	135	Steam	..	0	120	Hand	122.0	112.2	115.	13.8	11.5	..	125	120	3	....
32	Municipal	24	1000	Steam	3	60	2300/110	Hand	115.0	104.3	109.	8.8	4.4	..	104	104	2	....
33	Private	24	2750	Steam	3	60	2300/115	Automatic	113.2	109.1	110.	5.2	4.4	2	115	112	O.K.-2	....
34	Private	24	675	Steam	3	60	2300/110	Automatic	111.0	104.5	108.	6.8	3.6	.	110	110	O.K.	....
35	Private	24	450	Steam	3	60	2300/115	Automatic	117.5	107.3	112.	10.7	5.1	.	115	115	2	....
36	Private	24	1500	High Ten'n	3	60	2300/115	Hand	119.4	107.0	115.	10.8	4.2	3	117	117	O.K.-4	....
37	Private	24	500	High Ten'n	3	60	2300/110	Feeder Regulator	113.0	110.0	111	4.4	3.5	.	112	112	O.K.	....
38	Private	24	160	Steam	1	60	1150/115	Hand	131. 118.	127. 114.	129. 116.	5.0	3.4	.	115	115	....	2.5
39	Private	24	195	Steam	2	60	2200/110	Automatic	103.	93.5	98.	6.5	2.0	.	110	110	....	2.
40	Private	24	125 30	Water Pow. Gas Engine	1 ..	133 0	1100/110 110	Hand	112.5	105.3	109.	6.3	2.7	.	110	110	2	....
41	Private	24	250	Water Pow. Steam	1	60	1100/110	Automatic	113.0	110.	111.	6.4	4.6	..	112	110	....	2. 4.5
42	Municipal	12	190	Steam	1	133	1100/110	Hand	111.5	100.	105.	12.7	8.3	..	110	110	....	....
43	Private	24	600	Steam	3	60	2300/115	Automatic	116.	105.3	110.	10.1	5.2	..	114	110	3	....
44	Municipal	24	700	Steam	3	60	2300/110	Hand	111.4	105.	108.	6.2	3.6	..	112	112	O.K.-4	....
45	Private	24	185	Steam	3	60	1100/110	Hand	112.5	103.6	107.	8.8	6.1	..	112	110	4	....
46	Municipal	12	190	Steam	3	60	2200/110	Hand	106.1	95.2	100.	11.4	4.7	.	115	115	5	....
47	Private	24	675	Steam	2	60	2200/110	Automatic	121.5	107.0	114.	12.3	6.5	..	117	115	O.K.	....
48	Private	24	300	Steam	1	133	1100/110	Hand	117.5	103.	109.	12.7	7.1	..	114	114	....	5.5
49	Municipal	24	300	Steam	3	60	2300/115	Hand	114.5	105.1	110.	10.5	5.2	2.5	115	117	3.5	....
50	Private	24	150	Steam	1	60	2200/104	Hand	114.8	109.2	111.	6.8	5.1	..	112	112	2	....
51	Municipal	24	400	Steam	3	60	2300/110	Hand	112.5	105.3	109.	7.9	4.4	..	114	114	6	....
52	Private	24	250	Steam	3	60	2200/110	Hand	112.3	106.5	108.	6.6	5.3	.	110	110	3	....
53	Municipal	12	350	Steam	1	60	1100/102	Automatic	103.5	95.	98.	8.6	5.8	..	104	102	....	2.
54	Private	12	175	Steam	..	..	250	Hand	286.	221.	228.	7.9	5.0	..	240	...	7	....

Central Station No.	Private or Municipal Plant	Service hrs.	K.w. Capacity	Source of Power	Phases	Cycles	Voltage Pri. Sec.	Method of Regulation	Line Voltage During Lighting hrs. Max.	Min.	Avg.	Drop in % of Plant Voltage Max.	Ave.	Max. Unbalance	Lamp Voltage Tung'n Fila'nt	Metal'd Fila'nt	Station Voltmeter Volts High	Volts Low
55	Municipal	24	600	Water Pow.	3	60	2300 115	Hand	115.3	107.5	109.	8.1	6.8	3	115	115	2 5	
56	Private	12	200	Gas Eng.	1	60	2300 110	Hand	110.2	96.3	104.	14.3	7.1	..	125	120	4	
57	Private	24	250	Steam	3	60	1100/110	Automatic	109 5	102.	105.	5.5	2.8	.	108	108	10	
58	Municipal	24	260	Steam	2	125	1100/110	Hand	112.1	105.2	108.	8.7	6.1	..	110	110	....	
59	Private	24	340	Steam	2	60	2200/110	Hand	112.4	104.0	109.	10.4	5.7	..	118	118	3	2
60	Private	24	325	Steam	3	60	2300 115	Hand	119.0	105.	109.	8.7	5.2	2.5	117	115	..	3 5
61	Private	24	3000	Steam	2	60	2000/100	Automatic	103.2	95.5	98.	7.3	4.8	..	100	100	O.K.	
62	Municipal	24	175	Steam	2	60	2300 110	Hand	123.8	115.	119.	6.5	2.7	.	120	120	....	3
63	Municipal	24	113	Gas Eng.	2	60	2300 110	Hand	118.	106.	111.	14.7	9.6	.	114	112	....	3 5
64	Private	24	560	Steam	3	60	2400/110	Automatic	135.0	113.	118 4	5.8	1.3	..	120	120	O.K.	
65	Municipal	24	750	High Ten'n	3	60	2400 110	Automatic	125.0	113.	119.	10.4	4.8	..	112	112	2 5	..
66	Private	24	2100 300	Steam	3	60	2300 106 220	Automatic	109 4	102.5	106.	6.8	3.6	..	108	106	O K.	
67	Private	24	140	Water Pow.		..	220 3 wire	Hand	117 5	99.	108.	14.7	6.7	2	112	110	1.5	
68	Municipal	24	225	Steam	3	60	2300/110	Automatic	119.0	114.3	117.	5.7	2.9	.	117	114	1	
69	Private	12	100	Water Pow.	..	..	220	Hand	223.	198.	213.	15.4	9.9	..	220	...	2 3	..
70	Private	24	300	Water Pow.	2	0	220 3-wire	Automatic	116	98.	112.	5.6	2.0	17	116	114	5	
71	Municipal	24	100	Steam	2	60	1100/110	Automatic	113 7	107.	112.	5.9	2.2	..	115	111	5	
72	Private	24	1500	Water Pow.				Automatic									1.5	
73	Private	24	600	Water Pow.	3	60	2300 115	Automatic	117.2	107.	112.	10.7	5.1	2.5	115	115	O.K.	
74	Municipal	24	150	Steam	3	60	2300 110	Hand	112.5	103.5	109.	9.0	6.8	..	114	114	3	
75	Private	24	150	Steam	3	60	1100 110	Hand	110	100.	107.	10.7	4.2	.	110	110	O.K.	
76	Private	24	75	Water Pow Steam	3 3	60 60	1100 110 1100/110	Hand	107.2 120.	99. 109.5	103. 114.	9.6 8.8	5.2 4.4	1.5	106	105	.... 1.5	1
77	Private	24	125	Steam	3	60	2300 110	Hand	112 5	106.5	110.	6.4	2 8	..	118 113	112 112	O.K.	
78	Private	24	475	High Ten'n	3	60	2300 113	None	125	97	112	17 8	5 1	2			....	2
79	Municipal	24	480	Steam	3	60	2200 110	Hand	116.	106.	112.	3.6	0.7	6	115	115	2	..
80	Private	12	130	Water Pow. Gas Eng.	1	60	2300 110	Hand	113.	104.	108.	10.5	6.1		115 117	115 117	O.K. 3 5	
81	Private	24	100	High Ten'n	3	25	2200 110	None	106.	100.	102.	No Meters			115	120		
82	Municipal	24	200	Gas Eng.	3	60	2300 110	Hand	110	104	110.	8.6	3 5	.	111	114	...	2

It will be noticed that the most economical voltage increases as the energy rate increases, and vice versa. The best voltage is also affected by the price of the lamp. List prices were used in computing the table, but for other prices the best voltage can be determined from the approximate rule that the most economical burning voltage increases about 1 per cent for every 10 per cent decrease in the price of the lamp. This figure applies to the tungsten-filament lamp only. For the metallized-filament lamp, the most economical voltage increases approximately 1 per cent for every 13 per cent decrease in lamp price.

The exact law from which this is derived is as follows:

Most Economical Voltage varies as $\left(\frac{\text{Energy Rate}}{\text{Lamp Price}}\right)^{a}$

in which expression "a" is 0.0986 for the tungsten-filament lamp and 0.0781 for the metallized carbon-filament lamp. This law applies both to the voltage at which the unit cost of light becomes a minimum and to the voltage at which the net revenue to the station becomes a maximum.

(Adjourned.)

SECOND TECHNICAL SESSION

WEDNESDAY MORNING, JUNE 12

THE CHAIRMAN, MR. F. M. TAIT: The first item on the program this morning is the Report of the Committee on Terminology, Mr. W. H. Gardiner, New York City, Chairman.

REPORT OF THE COMMITTEE ON TERMINOLOGY

The Committee on Terminology submits herewith a list of terms, the definitions of which it has drawn up.

The committee confined itself to the definition of terms directly pertaining to the central-station business rather than broadening its field to include the consideration of terms of a scientific and physical nature, which latter it felt were best handled by the committee of the American Institute of Electrical Engineers.

Certain terms and definitions which pertain especially to accounting matters were also considered by several members of the committee, but it was deemed desirable to leave these in the hands of the Committee on Uniform Accounting.

The Committee on Terminology also drew up some definitions of various rate terms which in essence coincide with the definitions which have been adopted by the Rate Research Committee. These latter are therefore appended to this list, credit being given to the Rate Research Committee.

Respectfully submitted,

Committee
- W. H. GARDINER, *Chairman*
- R. S. HALE
- A. S. LOIZEAUX
- CHAS. F. SCOTT
- CHAS. P. STEINMETZ

TERMS DEFINED BY THE COMMITTEE ON TERMINOLOGY

Capacity Factor

The ratio of the highest experienced load for a specific interval of time to the maximum capacity for this same interval.

EXAMPLE—A station whose highest average load during one hour has been 8000 kw, and whose maximum capacity for the same interval, one hour, is 10,000 kw, would have a capacity factor of $\frac{8000}{10,000} = 80$ per cent.

NOTE—The interval over which load is integrated should be

the same as the interval on which maximum capacity is based. This interval may be momentary, or five minutes, or one hour, etc., but should be stated in giving capacity factor. It will be seen that capacity factor cannot be greater than unity, and the difference between the capacity factor and unity is the margin available for growth, spare capacity, or emergency.

Demand

Demand is a load specified, contracted for, or used, expressed in terms of power, as kilowatt or horse-power.

NOTE—The interval of time considered should be specified.

Diversity Factor

The ratio between the simultaneous demand of a number of individual services for a specified period, such as one hour, and the sum of the individual maximum demands of those services for the same period.

NOTE—Diversity factor is expressed in per cent, and can never be greater than unity unless expressed in terms of its reciprocal.

Effective Demand

The demand at the time of the system's maximum load.

NOTE—This can be applied to an individual customer, feeder, or station.

EXAMPLE—If the maximum demand occurs on an electric system at 5 p. m. December 20th, the effective demand by an individual service would be the demand of that service at the hour mentioned.

Feeder

An electric circuit used to supply power to a subsidiary distributing system.

Instantaneous Value

The value of varying quantity at a particular instant, as distinguished from a value averaged over a finite length of time.

NOTE The instantaneous value is the absolute value at any instant as given by oscillograph record.

Indicated Value

The value of a varying quantity as indicated by an instrument which averages the instantaneous values.

NOTE—Indicated values are given by common ammeters, voltmeters and other electrical instruments, as they average the values of sine wave or fluctuating current, due to their inertia or dead-beat qualities.

Indicated Peak

A peak load as given by an indicating instrument.

Integrated Peak

A peak load as given by an integrating meter for a period of time corresponding to the duration of the peak.

Connected Load-Factor

The *Connected Load-Factor* is the ratio (stated in per cent) of the kw-hr. registered by a watt-hour meter during any given period (as a day, a month or a year) by any connected load, to the kw-hr. which would have been registered due to same connected load during the same period (day, month or year) if all the apparatus making up this connected load had continuously consumed its full normal kilowatts (rate of current at normal voltage) during the entire period.

NOTE—Where the kw-hr. readings are not available, the kva-hours should be substituted. In certain cases, notably alternating-current generators and transformers, the kva is more important than the kw, if their capacity is being considered.

Capacity Load-Factor

The *Plant Capacity Load-Factor* is the ratio (stated in per cent) of the kw-hrs. actually delivered by a plant (or by any specific section of a plant such as series direct-current) during any given period (as a day, a month, or a year) to the kw-hrs. which the same plant (or the same section of it) would have sent out had it operated throughout the same period continuously at its full normal rating.

NOTE—Where the kw-hr. readings are not available, the kva-hours should be substituted.

Demand Load-Factor

The *Maximum Demand Load-Factor* is the ratio (stated in per cent) of the kw-hrs. actually delivered by a plant (such as multiple direct-current) during any given period (as a day, a month, or a year) to the kw-hrs. which the same plant (or the same section of it) would have sent out had it operated throughout the same period continuously at the maximum rate recorded.

NOTE—Where the kw-hr. readings are not available, the kva-hours should be substituted.

Daily Load-Factor

The load-factor obtained by taking the mean load for one day, and dividing it by the peak load during that day.

Yearly Load-Factor

The load-factor obtained by taking the mean load for the year, and dividing by the peak load recorded during that year.

Integrated Value

The summation value of varying quantity over a definite period of time.

NOTE—The readings of watt-hour meters are integrated values, and are read by taking the difference between readings at the dial at the beginning and end of a definite interval of time.

Maximum Demand

The highest demand measured in a manner agreed upon or stated.

NOTE—The maximum demand may be based on the reading of a watt-hour meter for one hour, one-half hour, or any other period of time, or upon the readings of an indicating instrument, in which case it should be called maximum indicated demand.

Maximum Indicated Demand

The highest load reached in a stated interval as given by an indicating or curve-drawing instrument.

Maximum Simultaneous Demand

The highest load at any time required to supply a number of individual equipments.

NOTE—The maximum simultaneous demand must be less than the sum of the individual maximum demands, if the latter do not occur at the same moment.

Peak Load

The highest load carried during a specified interval of time.

NOTE—Both the method of measuring the peak load and the interval of time covered should be specified. Thus, daily indicated peak load, or yearly peak load, for one hour, are correct expressions.

Simultaneous Demand

The sum of the demands, or load existing at the same time on a number of services.

NOTE—The simultaneous demand cannot be greater and will generally be less than the sum of the individual demands.

Watt-Hour Meter

An instrument registering watt-hours passing through an electric circuit. This term should be used in place of "Integrating" wattmeter, or "Recording" wattmeter.

DEFINITIONS GIVEN BY RATE RESEARCH COMMITTEE

1—*Flat Rate*

The term *Flat Rate* is applicable to any method of charge for (gas or) electric service which is based on the consumer's installation of energy-consuming devices or on a fixed sum per consumer, irrespective of the quantity used. Meters are not used.

2—*Demand Rate*

The term *Demand Rate* is applicable to any method of charge for (gas or) electric service which is based on the maximum demand during a given period of time. The demand is expressed in such units as kilowatt or horse-power (or rate of flow of gas). Maximum-demand indicators or graphic meters are used.

3—*Meter Rate*

The term *Meter Rate* is applicable to any method of charge for (gas or) electric service which is based on the amount used.

This amount is expressed in such units as kilowatt-hours of electricity (or cubic feet of gas). Integrating meters or graphic meters are used.

The charge may be in proportion to the number of units, or it may change in proportion to the number of units, in a manner specified.

4—*Consumer's Output Rate*

The term *Consumer's Output Rate* is applicable to any method of charge for (gas or) electricity service based on the consumer's output. The unit of the consumer's output may, for example, be a gallon of water pumped, a barrel of flour or a ton of ice made, etc.

5—*Two-Charge Rate*

The term *Two-Charge Rate* is applicable to any method of charge for (gas or) electric service in which the price per unit of metered (gas or) electric energy for each bill period is based upon both the actual or assumed quantity of (gas or) electric energy consumed and the actual or assumed capacity or demand of the installation. (Example—The Hopkins Rate.)

6—*Three-Charge Rate*

The term *Three-Charge Rate* is applicable to any method of charge for (gas or) electric service in which the charge made to the consumer for each bill period consists of (a) a sum based on the quantity of (gas or) electric energy consumed, (b) a sum based upon the actual or assumed capacity or demand of the installation, (c) a charge per consumer. (Example—The Doherty Rate.)

7—*Straight Line*

The term *Straight Line* as used in connection with and as applied to any method of charge indicates that the price charged per unit is constant, *i. e.*, does not vary on account of any increased or decreased number of units. The total sum to be charged is obtained by multiplying the total number of units by the price per unit.

8—*Block*

The term *Block* as used in connection with and as applied to any method of charge indicates that a certain specified price per unit charged for all or any part of a block of such units and reduced prices per unit are charged for all or any part of succeeding blocks of the same or a different number of such units, each such reduced price per unit applying only to a particular block or portion thereof. The total sum to be charged is obtained by multiplying the number of units in the first block by the price per unit for that block and adding thereto the number of units in the second block times the price per unit for that block, and so on until the sum of the units falling within the different blocks equals the number of units to be charged for.

9—*Step*

The term *Step,* as used in connection with and as applied to any method of charge, indicates that a certain specified price per unit is charged for all or any part of a specified number of units, with reductions in the price per unit based upon increases in the number of units according to a given schedule. The total sum to be charged is obtained by multiplying the total number of units by the price applying for this number of units or by the primary price and deducting the discount applying for this number of units.

DISCUSSION

Mr. L. N. Peart, Fresno, Cal.: I would like to ask a question concerning connected load-factor. In the Report just presented the last part of the definition reads "* * * if all the apparatus making up this connected load had continuously consumed its full normal kilowatts (rate of current at normal voltage) during the entire period." Now in alternating-current voltage what power-factor would you allow if you took the amperes and volts as marked on the meters?

Mr. Gardiner: I should say that would depend entirely on the conditions of each installation. In other words, the point you are raising is, as I take it, whether the load-factor be a kilovolt-ampere load-factor or a kilowatt load-factor.

Mr. Peart: If it is a kilowatt load-factor, how do you determine it? You surely have to allow for deficiency of power-

factor in your load if you use the current in voltage. That is the point I am bringing up.

MR. GARDINER: Yes, you should make that allowance in operation, and you should be guided by the definition. There is a note on that connected load-factor; where the kilowatt-hour readings are not available the kilovolt-ampere hours should be substituted. In alternating generators and transformers the kilovolt-ampere hours are more important than the kilowatt hours. Under those circumstances one would naturally use the kilovolt-ampere readings rather than the kilowatt readings, and in stating such load-factors and comparing them with kilowatt load-factors they should be stated as kilovolt-ampere load-factors.

MR. PEART: If you are comparing the readings of an integrating wattmeter I should think you would have to.

MR. GARDINER: Where you have part in kilovolt-ampere hours and part in kilowatt hours you certainly would have to take it, and you would have to determine it for each set of circumstances or set of installations if not for each individual one.

THE CHAIRMAN: Is there any further discussion on this report? If not, we will listen to the next paper, "New Current-Consuming Devices," by Mr. F. N. Jewett, St. Louis, Mo.

NEW CURRENT-CONSUMING DEVICES OF INTEREST TO CENTRAL STATIONS

Less than one-fifth of the central stations in the United States are provided with direct-current apparatus, and the number of companies using direct current is actually decreasing while the number of companies using alternating current is rapidly increasing. Yet there are many uses for which direct current is required, perhaps the most conspicuous at the present time being the electric-vehicle battery. The electric vehicle is becoming more and more a factor as a customer of the central-station company, and its use bids fair to increase at a tremendous rate. The moving-picture show is a comparatively new form of public entertainment, but it has nevertheless already established itself so thoroughly as to be assured of permanency. For the picture machine, direct current furnishes steadier and whiter light, with a decidedly smaller consumption of current at the arc, than is possible with alternating current.

In addition to these two principal users of direct current there are many other purposes for which it seems peculiarly and uniquely suited. The market has offered numerous devices for changing alternating to direct current, but in them all objections exist, and these objections in some cases are very weighty.

It is my purpose to consider only comparatively small devices of 5-kilowatt capacity and less. The well-known 25-cycle rotary transformer commonly used in street railway work does not come within the scope of this discussion.

Motor-generator sets have been largely used, consisting of an alternating-current motor connected to a direct-current generator. Such an outfit is very reliable in operation but seriously defective in its low efficiency. The small motor has an efficiency of approximately 75 per cent and the generator a similar efficiency, the over-all efficiency of the outfit being approximately 55 per cent.

From time to time there have appeared many ingenious and some curious forms of mechanical rectifiers, such as revolving commutators, contact makers, etc., but always with the early demonstration in practise that their usefulness is limited to

comparatively small amounts of current, too small to be commercially available for vehicle batteries and moving-picture shows.

The urgent need of a reliable, efficient and simple device has, for many years, caused engineers to strive diligently to produce a single-phase converter (to be the full equivalent mechanically of a motor-generator set) in a single unit capable of operating from single-phase alternating-current supply and capable, further, of producing direct current through a wide range of voltages without the introduction of wasteful resistance.

THE SINGLE-PHASE ROTARY CONVERTER

The Wagner Company has now produced such a device, building it in several capacities ranging from 2 kw to 5 kw, and adapted particularly to the following purposes: Battery charging

FIG. 1—ROTARY CONVERTER, FOR USE AS ALTERNATING-CURRENT OR DIRECT-CURRENT MOTOR OR FOR THE CHARGING OF ELECTRIC VEHICLE BATTERIES FROM ALTERNATING-CURRENT SOURCES

for electric vehicles, moving-picture and theatrical work, forming storage batteries, X-ray and similar work, charging telephone batteries, energizing telegraph systems, railway signal work and miscellaneous industrial use. This equipment consists essentially of the following parts:

(a) The converter proper as illustrated in Figure 1. It will be seen from Figure 1 that the converter to all outward appear-

ances resembles the standard single-phase alternating-current motors built by the same company. The frames are substantial, the bearings liberal and the construction in all respects is rugged.

Before the advent of this machine the difficulty with single-phase or polyphase rotaries, especially in the small sizes, for 60-cycle work, has been the so-called "hunting" or instability and fluctuation of direct-current pressure with the slightest variation in alternating-current voltage or frequency. The converter is unique in the proportion of the windings and the use of the short-circuited winding in the stator to damp out hunting effects. The converter may be used as a power motor from either direct-current or alternating-current supply.

This statement at once answers the possible inquiry as to the starting of the converter. It may be started from either the alternating-current or the direct-current side, the usual procedure being to start from the alternating-current side, then operating as a series alternating-current motor and therefore having excellent starting torque and comparatively low starting current conditions.

The starting operations are comparatively simple, as will be noticed by an examination of the switchboard illustrated in Figure 2.

(b) The second part of the equipment is the switchboard with the controlling and starting apparatus. To place the outfit in operation, the line switch No. 1 is closed. The 4-pole, double-throw switch is thrown into the position marked No. 2. The converter is now connected as a series motor. When the converter has attained nearly full speed the four-pole switch is thrown over to No. 3. For battery charging work, the circuit-breaker No. 4 is then closed, thus connecting the outfit to the battery, and the handle on the switching dial No. 5 is moved around until the charging current is at the proper value required for the particular battery to be charged.

The switching dial No. 5 connects to the taps from the transformer on the back of the switchboard. It will thus be noted that the regulation of the amount of current required for the battery is obtained by changing the transformer taps and not by the introduction of resistance. As is well known in rotary transformers or converters, there is a definite and fixed relation

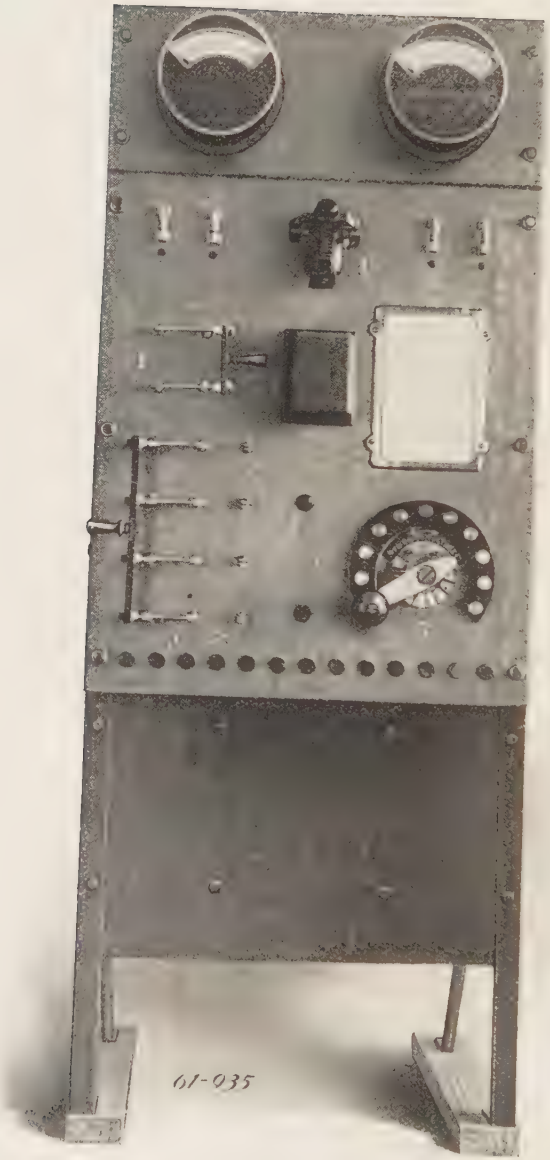


FIG. 2—SWITCHBOARD COMPLETE WITH INDICATING INSTRUMENTS, LIMITING DEVICES, ETC., FOR THE OPERATION OF THE CONVERTER AS MOTOR OR GENERATOR

between the alternating-current voltage input and the direct-current voltage output, the alternating-current voltage input being always approximately 70 per cent of the direct-current voltage output. It is apparent then that it is necessary to step the alternating-current voltage down to approximately 70 per cent of the desired direct-current voltage. For this purpose a transformer is furnished on the back of the switchboard. Each transformer is provided with a number of taps in both primary and secondary windings. The secondary taps are connected permanently to the slip-ring circuit and are provided for changing the voltage output through wider ranges, such as are required for vehicles having a different number of cells. The primary taps are connected to the switching dial or regulating head, No. 5, in Figure 2. This gives finer regulation of the voltage output as required in storage battery charging operations.

POWER-FACTOR

The central-station manager realizes to-day as never before the importance of maintaining the power-factor of his entire system at as near unity (or 100 per cent) as possible. He is keenly alive to the fact that his customers are paying him on the basis of kilowatt-hours used, although he must invest his capital upon the basis of kilovolt-amperes furnished. He realizes further that good service, satisfied customers and normal growth depend upon the best possible service and this in turn means good regulation.

It is a truism that regulation is best when the system is operating at 100 per cent power-factor, and the regulation grows worse and worse as the power-factor diminishes in percentage. Current-consuming devices, especially power devices, with inherent high power-factor, are to-day engaging the attention of central-station managers to a marked degree, and this particular device should be especially attractive to central-station managers, in that it operates at practically unity power-factor. The over-all efficiency of the entire outfit is comparatively high. On account of the high power-factor the apparent efficiency is excellent.

It may be interesting to note here that the Cleveland (O.) Electric Illuminating Company has filed with the Public Service Commission of the State of Ohio a rate schedule of power in

which power-factor is taken into consideration in figuring power bills. Their schedule reads as follows:

> "The company reserves the right to test the power-factor of the consumer's load and if the average power-factor differs from the following schedule namely:
>
> | | | | | | | | | | | |
> |---|---|---|---|---|---|---|---|---|---|---|
> | 75% | power-factor | for | demands | from | 5 | kw | to | 50 | kw |
> | 80% | " | " | " | " | " | 50 | " | " | 250 | " |
> | 85% | " | " | " | " | " | 250 | " | " | 1000 | " |
> | 90% | " | " | " | " | above | 1000 | " | | | |
>
> then the monthly kilowatt-demand shall be corrected and determined in accordance with the formula: Kilowatt demand as measured DIVIDED BY average power-factor of load MULTIPLIED BY allowable power-factor of load."

Under such a schedule as this, high power-factor apparatus becomes distinctly attractive and economical for the customer as well as for the power company. In schedules where the power-factor is not considered, the customer is interested only and exclusively in the watt-consumption of the apparatus and is not concerned as to power-factor unless forced by the power company to purchase particular types of apparatus which are known to operate at high power-factor.

That this converter draws only 64 per cent as much current from the alternating-current line for a given direct-current output as other types of rectifier is largely in its favor, from the central-station point of view especially. The user would also be concerned about this if the power company took into consideration the power-factor of his load in making rates.

So far, we have considered this converter particularly as a device for furnishing direct current from an alternating source of supply. It should be noted that it may also be used as an efficient high power factor alternating current motor and may be applied to any power uses to which ordinary alternating-current motors are adapted. This converter will earn for the central-station company a greater revenue than the ordinary rectifier, because the user who installs this device will soon appreciate the motor feature. He will, in most cases, use the motor to operate at least an air pump for pumping tires and probably a buffing wheel for polishing the metal-work on his vehicle. There are some installations where the customer, finding out that he had a motor as well as a converter, purchased a complete home laundry

equipment consisting of rotary washer, power wringer and mangle, for facilitating household laundry work. Some users went a step further and added a first-class vacuum cleaning outfit. From the central-station point of view, then, the converter is an all-round revenue producer.

It is interesting to note, also, that this converter fills a decided want in providing for hospitals and surgeons direct current for use in connection with X-ray machines. It is well-known that for the practical operation of apparatus for X-rays, interrupted direct current is absolutely necessary. In order to produce the necessary voltage to "jump" the tube a step-up transformer or induction coil is always included as part of the X-ray equipment. The interrupted current produces in the secondary of the transformer or induction coil, which is of the open-core type, a very peaked wave form of insufficient pressure in the reverse direction to pass the tube, thereby confining the emission of X-rays to one terminal as desired. Practically speaking, an interrupted direct current of very high potential is obtained.

There is, however, even with this apparatus, a small amount of "inverse," that is, current flowing in the wrong direction. This is choked out by means of vacuum tubes, termed in the profession "valves," which act somewhat as check valves in hydraulic work.

In X-ray work, then, every hospital, every X-ray specialist who takes X-ray pictures and many other specialists who use X-rays for treating various skin diseases, need and require direct current for the work, and this converter is exceedingly well adapted for, and is filling a decided want in, this field.

THE SINGLE-PHASE MECHANICAL RECTIFIER

It is mechanically difficult, as stated above, to rectify alternating current in any large capacity. The small mechanical rectifier under discussion has been developed for small currents only and at low voltage, suitable particularly for charging 3-cell storage batteries with a normal discharge rate of 3 to 6 amperes. Such batteries are practically standard for automobile and motor-boat ignition and lighting.

Automobile lighting has gone through the same stages as the illumination of buildings. At first oil lamps were used, then

came gas; now electric lights are being applied increasingly for this purpose. The arguments, worn threadbare, as to the advantages of electric lighting over gas lighting for residence purposes, apply even more strongly to automobile use. Electric lights on automobiles are superior from every point of view; they give greater intensity of illumination, the light can be directed and used where desired, and is always available by just "turning the switch." This is equally true of the modern motor boat, an increasing number of which are being used each year.

Here then exists a field in which, in the aggregate, an enormous amount of electric energy will be used. While the problem is not acute at the present time, the central-station manager may well look at it squarely and inquire whether he is to secure the revenue obtainable from supplying lights to automobile and motor boats or whether this will be to him a forbidden field, because each vehicle or boat becomes in itself a small isolated lighting station with its own power plant, generator, storage battery and transmission system.

The electric lighting of automobiles and motor boats may be accomplished in one of two ways: 1st. The car may be equipped with a central station, very small and very compact, ingeniously arranged to disconnect the generator temporarily from the lighting system when the car is standing still or the engine not running. A storage battery should be provided also to "float on the line" for the double purpose of regulating the voltage supply to the lamps and providing lights when the car or boat is not running. There are several such systems on the market, some of them giving excellent service. They are, however, expensive, and add considerably to the weight of a car, as well as somewhat to its complications, which, for the ordinary motorist, are already sufficiently involved and complex.

2nd. The second way of providing electric lights is the straight storage-battery method. The car is wired and a storage battery, occupying a space of 8 by 8 by 18 inches, is placed on the running board. Such a battery when charged should be of sufficient capacity to supply all the lights on a car for 24 to 30 hours steady and continuous use. This is the simplest and cheapest system of providing lights and it is in every way comparable to carrying a tank of compressed gas, which, when depleted, is replaced by a filled tank. With the storage-battery

system no moving parts are involved and the minimum of additional weight is carried on the car. The battery capacity should be sufficient in everyday use to carry the car through a week or ten days, without either changing or re-charging.

For charging the storage battery direct current is required, as alternating current is not suitable. Inasmuch as 90 per cent of the electric current supplied by power companies throughout the United States is alternating current, we are confronted, in charging the battery for automobile electric lighting, with the problem of conveniently, simply and economically changing alternating current into direct current. Here again the company has taken the field, offering a small, portable, convenient rectifier for the particular purpose of changing alternating current into direct current for charging automobile and similar batteries. This rectifier is 12¼ inches long, 5¾ inches wide and 4¾ inches high and weighs 12 pounds. It consists of three parts in one case:

(1) A small two-coil transformer, the function of which is to reduce the voltage or pressure of the alternating-current supply (110 volts) to a low voltage suitable (after rectification) for charging the storage battery.

(2) The rectifier proper. This consists of a vibrating armature in connection with an electro-magnet.

(3) A resistance which limits the flow of charging current.

The function of the rectifier is to permit current flowing in one direction only to pass to the battery. This is accomplished quite simply by means of the vibrating armature above mentioned when operating in connection with the small transformer.

As will be noted in Figure 3, the rectifier is provided with a lamp cord terminal equipped with an ordinary extension plug which fits any convenient lamp socket. The storage-battery connections are from two substantial binding posts. It is immaterial which post is connected to the positive or to the negative terminal of the battery. The charging will proceed satisfactorily regardless of the way in which the positive and negative terminals are connected to the rectifier, and once connected, the operation begins automatically, requiring no attention.

If for any reason, such as the interruption of the current supplied, or trouble in the device itself, the rectifier should cease

operating, it always stops with the main contacts open so that the storage battery cannot be rapidly discharged, and charging will recommence automatically with a re-establishment of current supply.

Fig. 3.—Rectifier, for Changing Alternating to Direct Current of Low Voltage

The equipment required for first-class automobile lighting is as follows:

2 head lights, each 12 candle power	24	candle	power
2 side " " 2 " "	4	"	"
1 tail light	2	"	"
1 speedometer light	2	"	"
Total	32	"	"

High efficiency tungsten lamps burn 1.1 watts per candle on a 6-volt circuit. The above lamp equipment draws 6 amperes from the battery when all lights are burning, but all lights are not running all of the time. It is not necessary to burn the side lights when the head lights are on and *vice versa*, so that

the average draw when the car is running is approximately 5 amperes. When the car is standing and the side and tail lights only are burning, the current draw from the battery will be about 1½ amperes.

The usual procedure with this device is to leave the battery permanently on the car when there is electric current in the garage in which the car is kept. At night the driver simply connects the rectifier to the nearest convenient lamp socket and to the battery and turns on the current, allowing the rectifier to charge the battery during the night.

It will be further noted that the nature of the use to which the device is put makes it an off-peak load consuming device. An automobile is usually in use in the late afternoon and early evening hours when the electric company's load is heaviest, and the motorist will charge his battery from the later evening hours when the lighting load is falling off until morning when the ordinary power load comes on.

From every point of view, then, this is desirable load for the central station.

While the current consumed by the device, 60 watts approximately, is comparatively small, during off-peak hours it is worth while to the central station.

In fact, automobile lighting is on a small scale exactly the same problem as the isolated electric plant problem in hotels, office buildings, factories, etc. We all remember when, fifteen years ago, it was considered practically impossible for the central station to compete with the isolated plant in installations of 100-hp and greater. We know now that if the central station had measured the problem then as it does to-day, many isolated plants would never have been installed.

There is no reason why the central station should not secure the business that will follow the general introduction of these two devices, the rotary converter and the rectifier, and it would apparently be to our advantage as an Association to aid in bringing about their use.

DISCUSSION

Mr. J. A. Lighthipe, Los Angeles, Cal.: I would like to ask Mr. Jewett if that small rectifier can be made to operate on fifty cycles.

Mr. Jewett: Yes, although it was first made and put out for 60 cycles. Inside of 90 days it will be ready for frequencies of 25 and 50 cycles, and in other capacities ranging up to 12 volts and 15 amperes.

The Chairman: Mr. Jewett, you state here that at night the driver simply connects the rectifier to the nearest convenient lamp socket and to the battery and turns on the current, allowing the battery to charge all night. Does the rectifier put itself out satisfactorily at the end of the charging period?

Mr. Jewett: It does not actually put itself out, but most of the small batteries are built in a very rugged way to stand considerable abuse, and if this device is put on for charging about once a week, it will hardly put into the battery during four hours' operation, a current that could in any way injure it. The batteries that are used are six-ampere batteries and if the car had been run for 20 hours before charging, that would be 120 ampere-hours. The rectifier supplying five or six amperes, say six amperes to the battery, would have to run over 20 hours to put back the same amount of current. Then, too, as the battery becomes charged, the rise in voltage tapers off the charging current automatically.

Mr. Farley Osgood, Newark: I would like to ask Mr. Jewett if this outfit is proper for a small garage. I do not mean the private garage, but one caring for several cars. Could more than one car be charged at a time with this outfit?

Mr. Jewett: Not with the small size. It is a small outfit. It has only six amperes charging capacity, and that is suitable for one battery only. The larger size, having fifteen amperes capacity could take on two batteries or even three, at a little lower rate. It is primarily a user's device. Some small garages have purchased it, however, where but few cars were in the place, and where charging one battery at a time would answer the purpose.

Mr. Osgood: I would like to ask, also, if it would be possible to develop an automatic cut-off device to be used in connection with this? It occurs to me that a man might connect his car, leave it and forget it. He might be unexpectedly called away and the battery run for two or three days. Could not an automatic cut-off device be developed to use in connection with it?

MR. JEWETT: Yes. The only difficulty is this: In order to keep the price of this down we have not added devices which increase the selling cost. A maximum-voltage relay and cut-out would cost about 50 per cent as much as the whole rectifier. That is the only reason for not supplying it regularly. It can be and will be furnished to those who wish to pay for it.

MR. OSGOOD: I am not a commercial man, but I would suggest for the good of those who own electric vehicles that you advocate the sale of complete outfits, as batteries are expensive.

MR. N. A. NAYLOR, Portland: I would like to know if there is one of these on display in the show room at the present time, and what is the approximated cost of the charging outfit?

MR. JEWETT: There is one of the smaller machines on display in the Wagner booth. It is charging a battery and running two lights. As to the second question, this device sells for approximately $25 to the user.

MR. C. J. WILSON, San Francisco: I would like to ask if both halves of the waves are rectified or but one half. In other words, is the current intermittent or similar to that of the mercury rectifier?

MR. JEWETT: In the small device I am displaying only one half of the wave is picked off. The current supplied to the battery is an interrupted unidirectional current. In the larger sizes the rectification will be accomplished by two vibrators, one of which will pick off one half of the wave and the other the other half. That will probably be an interrupted current still, although both halves of the waves will be used and the battery will get twice as many impulses.

MR. WILSON: Following that question, what would be the efficiency of the present development, theoretically?

MR. JEWETT: The actual efficiency of the present rectifier is approximately 50 per cent. However, when one considers its very small capacity, five amperes at six volts, it is a rather higher efficiency than could be obtained from almost any other kind of device, and is about as high as could be expected from such a small machine. The efficiency is not of much importance when one considers that its consumption is sixty watts.

MR. OSGOOD: Have the designers of this rectifier made any progress towards perfecting the device in large capacity for the use of magnetite street lamps, continuous current? There

would have to be an uninterrupted current. We are waiting for it if it can be made.

MR. JEWETT: We shall keep it in mind, but this device would not do it.

THE CHAIRMAN: If there is no further discussion on Mr. Jewett's paper let us take up the next, "Twenty-Four Hour Service in Small Central Stations," by Mr. Taliaferro Milton, of Philadelphia. The paper will be read by Mr. George R. Murphy, San Francisco.

24-HOUR SERVICE IN SMALL CENTRAL STATIONS

It is a well-known fact that the consumer of electric current in the larger cities is each year demanding better service, and the large central-station companies are keeping pace with this demand by improving the service from year to year. The inhabitants of small towns are, in turn, beginning to wake up and increase their demand from year to year for better service. In the old days, the proprietor of the local power company in a small town could obtain a fair number of customers by running his plant from darkness to 10 P. M. or midnight. To-day it is becoming more and more difficult to obtain customers in the small town unless 24-hour service is furnished.

It has been proved in a great many cases that a continuous 24-hour service can be profitably furnished by means of a storage battery operating in conjunction with the generating apparatus, where such service without the aid of a battery would be impracticable.

With the load which is obtainable in some small towns where the installation of a plant is being considered, to operate only from darkness to midnight, it will sometimes be found that it does not pay to operate a plant at all. If it is attempted to give continuous service by operating the engines and generators for 24 hours per day it will sometimes be found that in the first few years of operation the venture is unprofitable because of the poor load-factor and resulting poor efficiency, and, in larger measure, to the labor item during the day and the early morning hours when the load is so small that the revenue is insufficient to cover the expense.

Even in the old days when the consumer did not demand a 24-hour service, it was found that by furnishing this service without continuous running of the generators, profits could be considerably increased.

The examples quoted below indicate what has been accomplished in the past by small central-station companies prepared to furnish 24-hour service without continuous operation of their generators and without any additional labor for the day shift. If such results were possible in the old days, when the customers'

demands were not as great as they are to-day, and when the power company had to make strenuous efforts to obtain a day load, it is easily seen that to-day, when the customer is demanding day service and is more than willing to supply the load, even better results can be obtained by furnishing 24-hour service without the necessity of operating the engines and generators throughout the entire period.

In quite a large percentage of the small towns scattered throughout the country, it will pay to install the direct-current system, using either a 110-volt, 2-wire system, or a 220-volt, 2 or 3-wire system, depending upon the load and the radius of distribution. Certainly nothing is gained by installing an alternating-current system in a small town with a small radius of distribution and a comparatively small load. Using the direct-current system it will usually be found that in the beginning of operation the load from midnight till dark the next day, can be profitably carried on a storage battery. With a direct-current plant equipped with a storage battery for carrying the entire load during periods of light demand, it will not usually be found necessary with a new plant to operate the engines and generators more than 8 hours per day, say from 4 p. m. till midnight. During these hours, the battery can be charged, thus improving the load-factor and decreasing the generating cost per kilowatt-hour. The battery can then carry the entire load until starting-up time the next day. In this manner the plant can be operated to give 24-hour service with only one labor shift. It has frequently been found that the increased efficiency of the generators, caused by the additional load due to charging the battery, results in delivering the day load from the battery with scarcely any appreciable increase in the fuel bill. This means that the added revenue obtained from the day load is gotten with little if any operating cost, practically the only cost for turning out this day load being the fixed cost on the battery investment.

If the battery plates are installed in containing vessels of sufficient size to allow for increasing the capacity of the battery by the addition of more plates and if the day load increases above the capacity of the initial battery installation, it will be a simple matter to add more plates to each cell and thus keep up with the load requirements. If, after a few years of operation, the load

increases beyond the ultimate capacity of the battery, and if the battery capacity has been wisely chosen in the beginning, it will usually be found that when this point is reached, the load will be of sufficient magnitude to make it pay to operate the generators over a longer period of time, or perhaps for the entire 24 hours. In cases of this sort the battery has enabled the operator to build up a day load of sufficient magnitude for economical 24-hour operation of the generators.

The battery question thus resolves itself into three propositions: First, in towns where no plant is operated at present and where a sufficient number of customers for profitable operation cannot be obtained without giving 24-hour service and where if 24-hours service were attempted, by running the generators continuously, the load-factor would be such that the plant could not be operated at a profit.

Second, where plants are now in operation giving service from darkness to midnight only and where the 24-hour load-factor is such that it would not pay to operate the generators continuously, and it can be shown that by giving 24-hour service by means of a storage battery, additional net revenue can be obtained.

Third, where plants are now operated during darkness only and where a 24-hour service even with a battery will not show immediate profit, with the present connected load, but where, if a storage battery were installed to enable the plant to give 24-hour service the giving of such service would soon result in building up the load to a point where 24-hour service would prove profitable.

I cite below a few examples of these various classes of service:

The New Windsor Electric Light and Water Company, New Windsor, Md., in 1899 installed on their 2-wire, 220-volt direct-current system a battery having a normal capacity of 120 amp. hrs. With this equipment the engine is started up at dark and runs until 10 p. m., during which time it carries the load and charges the battery. When the engine is shut down the load is about 15 to 20 amperes, dropping to 2 or 3 amperes at midnight, which load continues until morning. The day load

varies with the season and weather. It would be practically impossible for this plant to maintain the same character of service without the battery, as the cost of running the generator on the extremely light load would be prohibitive.

An interesting example of a case where the load can be built up with the aid of a battery to a point where it pays to operate the generators for 24 hours, is the Jordan Electric Light Company, Jordan, Minn. In the Spring of 1905 they installed a 280-ampere-hour, 220-volt, 3-wire battery. At that time the town had about 1400 inhabitants. When first installed the battery was of ample size to carry the entire load from midnight until lighting time the next evening. As soon as the customers found that current was available at all times, they began to install current-using apparatus until it soon became necessary to run the engine a few hours each day. This company through its battery has built up a load of sufficient magnitude at present to warrant 24-hour operation of the engines and generators.

The Chester Electric Light Company, Chester, Mass., have a 110-volt, 160-ampere-hour battery. The service obtained from this battery varies widely, due to changes in the load and the supply of water. With an abundance of water the battery is floated continuously across a generator run by a water-wheel. At times of low water the battery is very useful in assisting them during the peak load, and carrying the entire midnight and early morning load. At such times a gas engine is in operation from 6 p. m. to midnight, carrying the lighting load and charging the battery. There are two dynamos of similar capacity; one run by the water-wheel, and the other by the engine.

Ira Beyer, at Mishicott, Wis., who is furnishing town lighting, operates a 3-wire, 220-volt, 80-ampere-hour battery. This battery was installed in conjunction with a water-wheel driven, 2-wire, 220-volt generator. The neutral of this system is established from a balancing set when the generators are in service, and directly from the battery when the generators are shut down.

Some additional interesting examples which fall under one or more of the above cited general cases are as follows:

The Ireton Electric Light and Power Company, Ireton, Iowa, where they have a 110-volt, 2-wire battery of 240-ampere-hour capacity.

H. B. Day, at Thurman, Iowa, where they have a 110-volt, 2-wire battery of 200-ampere-hour capacity.

F. M. Sadler, at Ellsworth, Minn., where they have a 220-volt, 3-wire battery of 160-ampere-hour capacity.

New Egypt Light, Heat and Water Company, New Egypt, N. J., 220-volt, 2-wire, 120-ampere-hour battery.

Joseph Duddleston, La Valle, Wis., 110-volt, 2-wire, 280-ampere-hour battery.

Lomira Electric Light and Power Company, Lomira, Wis., 220-volt, 3-wire, 120-ampere-hour battery.

In taking up the question of storage battery for a small plant, the problem to be determined is as follows:

From the estimated or existing load curve, determine how much battery capacity is needed to carry the load during the hours when it is unprofitable to run the generators. The price of the necessary battery having been obtained the fixed charge against the battery investment can be conservatively estimated at about 15 per cent, which includes maintenance, interest, insurance and taxes. If the revenue obtainable from the load to be delivered by the battery exceeds by any appreciable amount this fixed charge, it will usually be found that the battery is a paying investment. The cost to charge the battery is practically nothing, due to the fact that the battery charging current, by increasing the load-factor on the generating apparatus, increases its economy to such an extent that the saving in the cost per kilowatt-hour for the current generated will nearly offset the cost of the power charged into the battery.

If sufficient revenue cannot be obtained at the start, from the load to be delivered from the battery, to pay for the fixed charges against the battery, it may pay to put in the battery to build up the load.

No extra labor is required for the battery installation, and usually a saving in labor can be effected by the battery.

In small plants no extra building for the battery is usually required, as the battery can be placed in a corner of the power-house.

While many more cases might be cited where storage batteries are proving a good investment in this service, the cases chosen are typical of what is being done and demonstrate the advantages to be obtained by their use.

DISCUSSION

Mr. J. B. Crane, Duluth, Minn.: On page 395 Mr. Milton states that after the battery investment the fixed charges can be conservatively estimated at about 15 per cent, which includes maintenance, insurance and taxes. I note that the list does not include depreciation, and I would like to know the approximate life of the batteries and about how often the plates have to be changed.

Mr. Murphy: In the figure of 15 per cent the depreciation is taken care of. It is impossible to state exactly what the life of the plates is going to be, because it depends more or less upon the service the battery is called upon to give. On the Pacific Coast the life obtained from the positive plates in small batteries is averaging about six to six and a half years. Does that answer the gentleman's question?

A Delegate: In the smaller towns, such as have been cited in this paper, it is usually unprofitable to operate a plant either on the short-hour basis or on the 24-hour basis, but there is a constant demand for 24-hour service at all times. Now I would like to inquire of Mr. Milton if he can cite us some examples where these small plants have been changed from a non-profitable to a profit-making basis by installing a battery and giving 24-hour service.

Mr. G. H. Atkin, Chicago: I recall that in the cases referred to at Ireton, Ia., and Mishicott, Wis., it was found advisable to put in tanks of almost double the capacity of the elements and they filled them up in a very short time, which would seem to indicate that batteries in this service are successful, because they increase the load very quickly. I think the success of these plants is shown by the increase in the number that are being put in each month.

Mr. Naylor: I would like to inquire, in a case where the plant is located some distance from your customers or the town that you serve, if you have a long-line transmission? If you should transmit on your continuous-current line to a distant point would you not have quite a loss to struggle with? As an example, I am at Goldendale, Wash. I have just finished up my first year. I have a plant of 150-kw. capacity, and I might say I inherited a 6600-volt generator which had a bi-weekly schedule for burning out. I cite this to show

you what can be accomplished in a 24-hour service without the battery. I went in there just a year ago this month, the first of this month, and they were operating only during dark hours. Eight days after I went in I started up the 24-hour service, and to-day I have six more than double the number of customers that I had at the start. I have two customers connected this week, who will make up an even 70 horse-power in motors with service throughout the year. You might think it would not pay in a small town to have the ordinary run of the blacksmith shops, the little planing mill, the ice plant, and so forth. We have a fixed charge on our motor service which really insures the fixed charges of our plant; that is, the 24-hour services pays for itself; and I am wondering whether in a case like mine, where our plant is ten miles from the place we serve, transmission from batteries would not be at quite a loss for that value of service.

MR. MURPHY: In a case similar to that cited by Mr. Naylor it would be out of the question to install a battery at the power plant and supply service to a town ten miles distant. That is obviously a question of high-tension transmission. This paper discusses the question of 24-hour service in small towns, and naturally, therefore, assumes a small radius of distribution. Ten miles would be absolutely impossible with any continuous-current system.

MR. OSGOOD: Without in any way discrediting this paper, I think that one or two points concerning it might well be brought out. I do not agree with the writer of the paper that it is desirable to install a continuous-current system even for a small town. It has been the experience of most of us that our business grows so rapidly that the original installation should be made of such a character as to take care of more or less long-distance work. I mean by that, work beyond the proper feeding distance for a battery. It should also be of such a character that it can be tied together with some other neighboring system.

I think that those who do not inherit systems should give careful consideration to the type of installation which they originally make. I doubt if anybody to-day would start out with a small continuous-current system unless it were an absolute necessity.

I have heard nothing as to the natural leakages of the lines which will, of course, work against the available capacity of the

battery. We all know that during rain storms and damp weather we have more or less loss through grounds on the lines, and the useful capacity of a battery, also, is going to be very much shortened by these natural line losses. That point is naturally and very properly omitted by the writer of the paper, who declines to say anything about the average life of the plates. I can say, from considerable experience, that storage-battery plates in service with the very finest care which well-trained men can give them may possibly last for ten years, but it is no difficult matter, without proper care, to ruin them in a year or two. I cannot agree with the writer of the paper that the life of the plates depends on the load put upon them, unless he means load put upon the plates by poor attention. The life in a storage battery depends quite as much on the attention the battery receives as it does on the load put upon it.

I think these gentlemen are very kind to bring to our attention the possibilities of the storage battery. Its use is increasing year by year, and it is well for us to know that when we are in a tight place we can get out in the way they suggest; but for a straight-away operating proposition, and as an operating man, I cannot recommend it, and I hope that the writer of the paper will not misunderstand the spirit in which I make this statement.

Mr. Murphy: Answering Mr. Osgood, I made a statement a short time ago that the life of the plates depends very much on the load put upon them. It is an established fact that the life of a battery is limited by the load placed upon it, that is, it is proportional to the ampere-hour output of the battery. That is a fact recognized by everybody.

Mr. Osgood: If it is properly cared for.

Mr. Murphy: Properly cared for—yes. While I can speak authoritatively only of experiences on the Pacific Coast, I have found in all cases that the number of ampere-hours obtained from available records is uniform in the different plants.

A Delegate: Mr. Osgood has touched upon several points which were in my mind, and I certainly endorse some of the comments made by him. I am trying to reconcile some of the figures given, particularly the statement on page 395 that 15 per cent includes the maintenance, insurance and taxes, and the further statement that is supposed to take care of depreciation. Based upon the figures given of the estimated life of the plates

as six to six and one-half years, there alone is a depreciation charge of 15 per cent at least on the positive plates. So with that fact in mind and making reasonable allowance for the other maintenance charges, it would seem to me that the 15 per cent is certainly a low figure. As a means of avoiding misunderstanding I simply bring up the point as to whether 15 per cent is ample margin.

THE CHAIRMAN: Mr. Murphy, will you tell us how much depreciation Mr. Milton is figuring on these batteries per year?

MR. MURPHY: I can answer that question and say there is ample margin, assuming the life of the positive plates to be six to six and one-half years. It should be remembered that the cost of new positive plates is not the total cost of the battery. In addition to the positive plates there are also the negative plates, the containing tanks and the installation costs. The cost of the positive plates per year is a small percentage of the total battery cost.

MR. LIGHTHIPE: I would like to ask Mr. Murphy if he has any record of the storage-battery plant on Mt. Hamilton, which is a typical two-wire storage-battery plant?

MR. MURPHY: I have a very good record of that. Possibly you remember the time it went in there.

MR. LIGHTHIPE: Before the earthquake. It was 1905, I think.

MR. MURPHY: It was either in 1905 or the latter part of 1904. We will assume it was about the middle of 1905, to be safe. I can assure you that there have been no plates purchased for renewal, and the only expense attached to that plant has been the purchase of three or four glass jars that were broken during some trouble with the engine, and about a dozen carboys of electrolyte. The cost of these, as you know, is very small. They have had no plates renewed in this battery.

MR. OSGOOD: I think we are all aware of the fact that the maintenance charges on battery plates come in all at once, hence I am not surprised at Mr. Murphy's statement. A battery which is well cared for will go on its way cheerfully for from six to ten years until it becomes time to renew the plates; then the charges have to be met. The pleasant story of no renewals continues to the seventh or eighth year, but in the ninth or tenth

year the costs are felt. We should not overlook this fact in considering the statement about this particular plant.

If I may make one more statement referring to the matter of starting with continuous-current service, I believe that in small towns which are destined to grow, the extra cost of a 24-hour service with alternating-current system will be cheaper for the investor than the putting in of a continuous-current system, buying a battery, and then throwing it all away in two or three years, as he will probably and properly have to do if business comes to him as it does to most of the men in this country.

MR. NAYLOR: I wish to say that my expense, operating the 24-hour service, does not exceed the 15 per cent the storage battery requires.

MR. OSGOOD: May I ask if that is not a water-driven generator?

MR. NAYLOR: Yes, water driven.

MR. OSGOOD: Well, the problem is different when you have to burn coal.

MR. NAYLOR: Well, the 15 per cent includes the labor.

MR. OSGOOD: In your case the charge is, of course, practically all labor?

MR. NAYLOR: All labor.

MR. OSGOOD: Those of us who have to use steam power, of course have a fuel charge, which is the largest charge in the production expense.

MR. P. H. KORST, Janesville, Wis.: I would like to know the approximate number of meters that can be run with this new engine plant from dark until 10 p. m. That undoubtedly refers to the winter time. In the summer in this country it would not work because you would have only an hour to run; but giving 20 hours on the battery, with 400 meters connected, you would find that the loss in the energizing circuit of the meters would do away with considerable of the battery capacity.

MR. MURPHY: I cannot answer that question for Mr. Milton. I am sorry he is not here. Of course I should make this statement. Every battery installation is fitted for the local conditions. You cannot figure on a special type or a specific number of cells and apply them to every individual case. It is

true in the case you cite that there would be a large load on the battery, but I know nothing about the number of meter connections in this particular case cited. Mr. Milton undoubtedly had it in mind, but I cannot give you accurate information on this point.

Mr. F. N. Jewett, St. Louis: As an inveterate attendant at conventions—and it has been necessary for me during the past six months to attend six or seven in the central west—I find this problem referred to particularly by Mr. Korst, this problem of the operation of 24-hour service as compared with short-hour service, is a vital problem for the managers of small stations. I have been struck at the various State conventions with the number of men who have made the statement that their plants in small towns were unprofitable until they provided 24-hour service. The introduction of the modern household heating and electrical appliances, washing machines, vacuum cleaners, flat-irons, cooking appliances, and all of these things that are used throughout the day has made it possible and profitable for some small plants to give 24-hour service. Some plants began by running 24 hours one day in the week only, perhaps to provide current for flat-irons; and this proved to be the entering wedge. I feel sure from what I have heard at other conventions that many plants which are now unprofitable with short-hour operation could begin to earn by giving 24-hour service.

Now, in justice to the storage-battery people I should tell one experience which I had some years ago. I was in charge of a small plant in Minnesota and it was a continuous-current plant. I got the storage-battery fever and secured from the owners of this plant an appropriation to buy and put in a storage battery so that we could actually shut down the engines which we were running unprofitably through certain hours. I went to Mr. Atkin, in Chicago, and submitted the whole proposition to him. He told me we did not have a battery situation at all, and frankly advised me not to buy. I feel personally from that experience that any proposition submitted to Mr. Atkin at least will receive fair consideration. [Applause.]

Mr. Osgood: Mr. Chairman, as I said before, I want it well understood that my criticism is not for the purpose of discrediting the paper in any way. We are all glad to have

heard the paper and to be told the possibilities of the storage battery, and I feel if Mr. Milton were here himself he would understand the fair and open criticism of the operating men with whom he deals so constantly.

I might say my personal experience has shown that without question the small plant, water driven, will pay on a 24-hour service, and that a small plant, steam driven, if changed from a night to an all-day service, will have to be backed up by a commercial campaign. It will take from one to two years to bring the plant up to a paying basis with 24-hour service, coal-driven generators.

Mr. G. H. Atkin, Chicago: Before we close I wish to personally thank Mr. Jewett for the bouquet he gave me, for which he will be rewarded after the meeting is over. [Laughter.] And I wish also to state that I think the member from Newark shows a lack of familiarity with the conditions in the west. The plants that are put in are usually original installations. They go into small communities which have been satisfied with kerosene lamps, and when it is known that they can have 24-hour service, owners of houses are prompt to take advantage of it.

Labor is a very important factor always, and these plants are run by one man who goes home at ten o'clock while his battery carries the all-night load. That is one reason why we are selling so many of these plants. As Mr. Jewett has said, very kindly, we do not hesitate to tell a man if he ought to have a generator instead of a battery. I think we are all disposed to give everyone a good show and a run for his money, but we feel we must combat this fear of excessive maintenance charges which is created by stories of a few batteries which have gone to pieces because of rotten attention, batteries which would have lasted for years with reasonable treatment.

Mr. Murphy: One point I would like to mention in reply to the speaker who stated that at the end of the seventh or eighth year the cost of new plates came as a rude shock when nothing had been heard of it previous to that time. It is, of course, assumed in maintenance that there will be set aside each year as a sinking fund, the amount of money necessary to take care of such expenses.

THE CHAIRMAN: Mr. Murphy, we thank you for reading Mr. Milton's paper. If there is no further discussion on that paper, let us pass to the next number, which is the Report of the Committee on Overhead Line Construction, Mr. Farley Osgood, of Newark, Chairman.

The report by Mr. Osgood will be oral; it has not been printed.

MR. OSGOOD: It would seem well to make a record of what has been going on in the Overhead Line Construction Committee this year. The first thing you should know is that the legal department of the Association, after the annual convention in New York last year, went into the matter of the retroactive effect of the 1911 report on the member companies. Mr. Burdett, the Association counsel, reported that there could be no dangerous effect, and the Executive Committee of our Association, in December, approved the report as submitted and commended it as a standard work for us to follow. That was the first step.

Second, the Association of Railway Telegraph Superintendents, which is a very strong organization as you all know, adopted the report verbatim. They threw away their specifications and sent the National Electric Light Association report out in their own covers, giving us credit for it, and it is now their standard.

The next move was with the American Electric Railway Association, which is the association of the trolley interests of the country. Their technical session, as we would term it, approved the report and recommended it for approval to their association standards committee. The standards committee referred it to a special sub-committee for consideration, their method in that association being that it takes two years always to bring about final formal results. This sub-committee has already considered the report and is going to recommend it, with the addition of two or three phrases in some of the paragraphs in order to broaden out the language in the way of explanation. They are not going to alter in any way the meaning of the report. We can, of course, do nothing until they take action as an association. Their method of procedure will be to recommend to their standards committee the adoption of the report with these minor modifications as their standard, and

this they can vote on at their next convention, to be held in Chicago this fall.

Another step in advance was with the steam railroads, the American Railway Engineering Association, it is called. It used to be called the American Railway Engineering and Maintenance of Way Association, but during the year they shortened the name. That association has a committee, called the committee on electricity, which considered this report, and I regret to say that they wanted to make a number of changes because they thought the rules of work should be much more stringent in a number of cases than the rules as finally agreed upon by the joint committee. When they held their convention in Chicago the 20th of March, this year, there was an attempt to change quite radically thirteen sections of this report which had been so generally adopted by everybody else. There was an excellent discussion on the floor, and the result was that only one section was changed, namely, Clause 18, which relates to the putting of strain insulators in guy wires. Some of the eastern roads had met with fatalities among their men on account of the guy wires getting against live wires when workmen were changing the foot locations of the guys, and the railroad men seemed to feel, especially as so many of them have their work near the water, that the strain insulator should be omitted in guys where it is known that the guys are through-grounded to permanently damp earth. In other words, they do not trust the strain insulator.

Therefore, since the steam railroad interests, earnestly desiring this one change, have given up 12 other changes, your committee, in conjunction with the joint committee on this work, has undertaken to have their addition to our Clause 18 adopted at this session.

We do not think that the change is in any way radical; it is not undesirable; and we feel that we are in honor bound, on account of the concessions which they made in order to come in with us on this standard work, to make this one change for them. I, therefore, as chairman of the joint committee, offer this resolution, which I trust will meet with the approval of this session. Be it

"Resolved, That strain insulators shall be used in guys from wooden poles carrying any power wire of less than 6600

volts; provided the guys are not through-grounded to permanently damp earth."

This last phrase was not in our original text.

And then comes the second paragraph, which relates to guys from poles carrying wires of higher than 6600 volts, which affects just this same point, namely:

"Strain insulators shall not be used in guying steel structures nor required on wooden poles carrying wires all of which are 6600 volts or more, provided the guys are through-grounded to permanently damp earth."

Gentlemen, I offer this as a resolution of change in our Clause 18.

A DELEGATE: I second the motion.

MR. C. J. WILSON, San Francisco: Mr. Chairman, is there to be any discussion on this?

THE CHAIRMAN: Yes.

MR. WILSON: I call your attention to the fact that the State of California has certain legislative enactments covering pole-line construction and on this particular point the law reads that there must be two strain insulators in all guys attached to poles carrying light or power wires. We should violate the State law in case we follow this specification. I do not know whether other States have this or similar laws, but as far as the State of California is concerned, it would be inadvisable to adopt the resolution before the session.

MR. OSGOOD: The committee realizes that municipal and State authorities will, from time to time, have conflicting specifications, and possibly laws, as in this case; and it further realizes that local companies must positively follow any local, municipal or State requirements. Where they conflict with the specifications you are, of course, exempt and have to follow your municipal or State requirements, just as you do in all agreements. I think that will cover the California conditions.

The drawing of this clause originally was for the purpose of protecting the lineman when he works on poles which are carrying live wires. In other words, insulators were required in guys from poles on which there were any wires of less than 6600 volts, because the linemen work on those wires when they are alive and should be protected from the ground.

On the other hand, the lineman will receive better protection if he does not have anything separating the wires from the ground on high-tension lines upon which he does not work when they are alive. You want the current to get into the ground from the high-tension lines. The wording is, I think, quite clear in that respect, and that is the object of the clause. I make this statement, as I expect some of you to ask why there is a difference in the method of the use of strain insulators. Generally speaking, linemen who work for lighting companies do not work on live wires when they carry 6600 volts or more. Does that cover your inquiry?

MR. WILSON: I think that is sufficient.

MR. LIGHTHIPE: We have already taken these standard agreements up with the Santa Fé and the Southern Pacific Companies. We simply modified the standard form of agreement to conform with the new laws of California, it being mutually understood that the changes were made to enable the utilities company to conform to the local law. There has been no trouble at all under the agreement, which has now been in force for at least three or four months. This standard form has been signed by the telegraphers of both the Santa Fé and the Southern Pacific railroads.

MR. OSGOOD: I thank you very much for that statement, Mr. Lighthipe, because that completely confirms what the joint committee thought would happen. No specification can hold against the local legal requirements.

The motion was put to vote and unanimously carried.

MR. OSGOOD: A year ago, when this specification was first introduced, that is, when the last section of it was first introduced, there was some discussion as to whether clamping devices would be required on 2400-volt service. It was not the intention of the joint committee to require clamping devices on our standard 2400-volt work, and it has been decided during the year that it would be well for that interpretation of the joint committee to be placed on record with the Association. The joint committee has asked me to make this further statement. It is a statement for record only. It does not change the specification, but simply puts us on record with our own interpretation, which is as follows:

"The interpretation of the National Electric Light Association of Paragraph 1 of Section 4 of the Report of the Over-

head Line Construction Committee, as presented at the 1911 Convention, is that the ordinary tie form of construction is proper for all 2400-volt railroad crossings, provided the construction conforms to the requirements of Section 1 of the report and applies only to voltages and conditions as covered therein and where the crossing span does not exceed 125 feet."

The other associations could not join with us and adopt this change of language in the paragraph headed "Scope," under Section 4, as it would write into their specifications if they did so, reference to another section of our report, namely, Section 1, which is a 2400-volt section, and in which they have not the slightest interest. It involved so much difficulty that it was decided the best way to handle the situation would be for the National Electric Light Association to go on record with its own interpretation, and I think there can be no objection to it on our part. I would offer this interpretation and ask Mr. Tait to give it a name as a statement which should go on record for the purpose explained.

THE CHAIRMAN: I hardly know what it should be called.

MR. OSGOOD: A statement of interpretation, I would suggest.

A DELEGATE: Would it not go in as a foot-note?

MR. OSGOOD: It is not to have anything at all to do with the specifications. Simply suppose some of us got into trouble with a railroad, maybe in court, maybe not. They say, "Here, you must use clamping devices." We shall be on record with something to which we can turn and say, "No, gentlemen, the interpretation of our joint committee is that on 2400-volt work, under ordinary conditions, we need not use them." We want something in the nature of an official record, that is all.

MR. LIGHTHIPE: Could it not be called Note A, or something of the sort?

MR. OSGOOD: It has nothing to do with the specifications.

MR. LIGHTHIPE: I suggest that it be put in as a preface to the specifications.

MR. OSGOOD: We do not want it in the specifications at all, because that would involve the other associations, and they have no interest in it.

THE CHAIRMAN: Where would you put this?

MR. OSGOOD: Just put it on file in Mr. Martin's office.

MR. HAROLD GOODWIN, Philadelphia: Mr. Chairman, I

move you that this interpretation be recorded in the minutes of this meeting as being the understanding of this meeting of the section to which it refers. I think that will put it on permanent record where it can always be found.

A DELEGATE: I second that motion.

THE CHAIRMAN: Is there any discussion? Is there any objection to it? All in favor of this motion kindly signify their intention by saying "Aye."

The motion was put to a vote and unanimously carried.

MR. LIGHTHIPE: I would like to ask Mr. Osgood one question concerning these grounding devices on the cross-over. They are very stringent in their requirements for this grounding device upon which the wire drops. We have complied with their request, but we have not the slightest faith in it on long lines, as it has no effect on the power unless the ground is absolutely good and the contact perfect.

MR. OSGOOD: You are speaking of the grounding device demanded by the State authorities?

MR. LIGHTHIPE: No; demanded in these specifications at high-potential crossings.

MR. OSGOOD: There is no specific mention of high potential, Mr. Lighthipe.

MR. LIGHTHIPE: The plan we have calls for them, the Southern Pacific calls for them and the Santa Fé calls for them.

MR. OSGOOD: There are no grounding devices recommended in the specification.

MR. LIGHTHIPE: What I mean is this rack which the crossing wires drop into if they break.

MR. OSGOOD: That is not in this specification. There is a particular clause stating that baskets, screens, and so forth, are not allowed.

MR. LIGHTHIPE: I do not call this a basket, it is simply a grounding hook.

MR. OSGOOD: There is nothing like that in the specifications.

MR. LIGHTHIPE: Then the specifications you refer to are not out yet, so far as I know.

MR. OSGOOD: Oh, yes, they have been out over a year.

MR. LIGHTHIPE: Well, I have not got them, because, as I have said, we are putting in this grounding device on the orders of both the Southern Pacific and the Santa Fé.

MR. OSGOOD: What is it, a ground plate for the broken wire to hit?

MR. LIGHTHIPE: Just in front of the suspension tops.

MR. OSGOOD: It is not tabooed. There is nothing about it in our specifications. The committee has no faith in it.

MR. LIGHTHIPE: Nobody has except the railroads.

MR. OSGOOD: They will outgrow that, just as they have some other things.

MR. LIGHTHIPE: I hope so.

MR. OSGOOD: We now desire to place on record for future reference of the members of the Association, the results of five wire crossing tests made on 2400-volt (approximately) crossings at Altoona, Eldorado and Philadelphia, in the State of Pennsylvania, and at Trenton, in the State of New Jersey.

The detail records of five tests made in conjunction with engineers of steam railroad companies follow:

Test No. 1—Eldorado, Pa.:

It was found that the insulators, pins and arms were in very good shape, the poles being slightly decayed at the base, but not sufficiently so to class them as requiring immediate renewal. The crossing consisted of three power wires and two telephone wires. The power wires were one No. 6 and two No. 4, insulated, 2300-volt wires. The crossing had been in service for approximately seven years.

The line was strung with spans of approximately 100 feet, with chestnut poles averaging 12 inches in diameter at the base. The line was straight for one span beyond the west side crossing pole; it then made a turn of approximately 20 degrees toward the south, with three or more spans in line. At the east side crossing pole, the line made a turn toward the north of approximately 18 degrees.

From this point the line was straight for four spans. At each of these turns the poles were guyed to and near the base of trees with No. 6 iron wire. These guys were installed so as to take strains equally from each of the spans adjoining. The west side crossing pole, where the wires were cut, had no guys. The general plan of the crossing and dimensions is shown on Plate 1.

The crossing pole top construction consisted of two sets of double 3¼-inch by 4¼-inch by 4-foot four-pin arms, the top arm supporting the three power wires on standard 1¼-inch wooden pins and Hemingray double-petticoat glass insulators. The arrangement of wires is as follows: The No. 6 wire on the outside south pin and the two No. 4 wires on either side of the pole. At pole C on the lower crossarm were supported two telephone wires on transposition insulators, below the No. 6 wire. Their location on the other poles was on the south side of the lower arm. The power crossarm was not equipped with braces nor with spacing blocks or bolts.

The power wires were tied with a standard horse-shoe tie of No. 6 wire; five ties having three turns around the line wire and the sixth tie on one side of the insulator being simply hooked over the line wire.

The contruction of the pole tops is shown on Plate 2.

Previous to cutting the power wires, careful measurements were made of the height of poles, above and below the elevation of the rail, and also the height of one power wire above the rail nearest the center of the span. The height of pole B above rail (to the wire) was 33 feet 1¼ inches; below rail, 7 feet 9 inches; pole C above rail, 30 feet 10⅞ inches; below rail, 8 feet 1 inch. The height of the No. 6 wire above rail was 31 feet 1¼ inches.

Two cameras were then set as firmly as possible opposite the two crossing poles and a very short exposure taken.

The ties on the telephone wires were removed from poles A, B, C and D. The No. 6 wire (outside pin) was then cut in the span adjoining the crossing span at a point approximately two feet from the insulators. The second wire was then cut, and then the third. As soon as all three were down, a second exposure was taken on the same film without moving the camera and also a second measurement of the height of the No. 6 wire above the rails; the result being 29 feet 3½ inches.

It was found that the ties did not slip nor the pins, crossarms or poles break under the strain given to them in this trial. The poles were deflected. This movement of the poles is shown on Plates Nos. 3 and 4. On examination of the ground around the pole bases no evidence of movement could be distinguished.

An effort was made to measure the deflection of the poles by means of plumb bobs, but it was found that the continual movement of the bobs, due to wind, was so great that no results were obtained. The ties on the telephone wires had to be moved approximately four inches for replacement. This agrees very well with the movement shown by Plate No. 5.

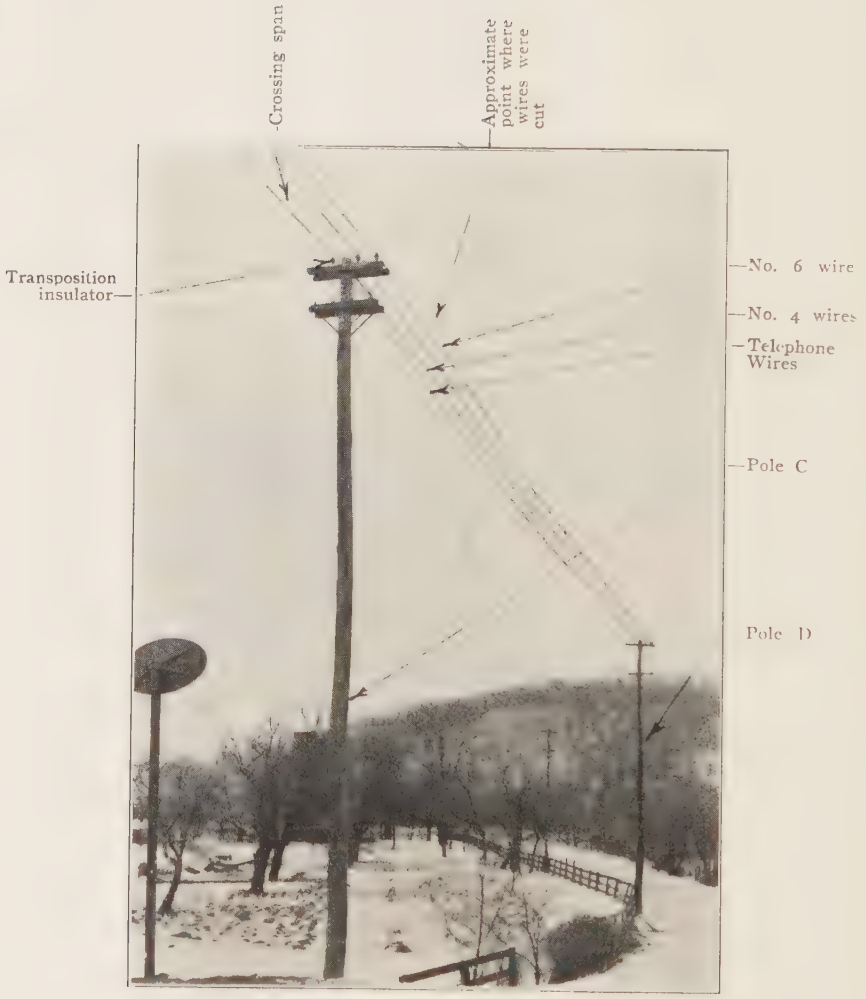
Another exposure was then taken of each of the crossing poles as the line was being repaired and again on the same film after the line was repaired. These plates, No. 3 and No. 4, show little or no pole movement, which would indicate that the previous deflection had been removed prior to the first exposure on these films, or that the deflection was not removed in repairing the line. Judging from the sag, part of the deflection, but not the entire amount, was taken up as the first line was pulled up.

Attached hereto are the detail figures and the method of arriving at the tension in each of the crossing wires before and after being cut. These figures show results as follows:

	Tension			Fibre Stress
	No. 6 Wire Pounds	No. 4 Wire Pounds	Strain Pole C Pounds	Base of Pole C Pounds
Before Cut	97.5	142.8	Balanced	.....
After Cut.....	29.6	43.4	116.3	315.7

It might be interesting to note that the strain on the No. 6 wire was 27.8, and on the No. 4, 25.5 per cent of the allowable strain under the maximum conditions of loading, as required in most of the present railroad company specifications.

It will be noted in this test that satisfactory conditions obtained without the use of any special tying devices.

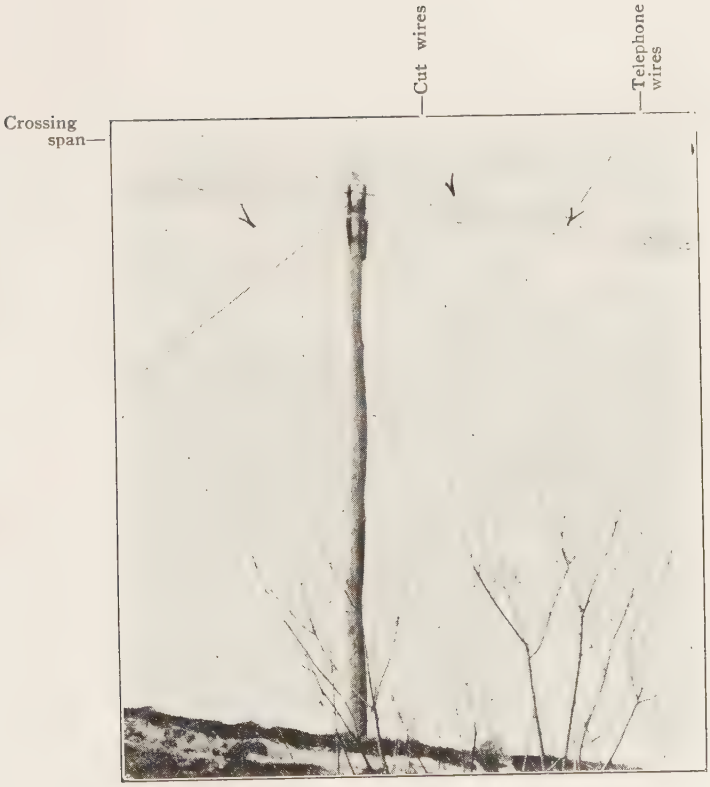


POLES C AND D
TEST I—PLATE 1

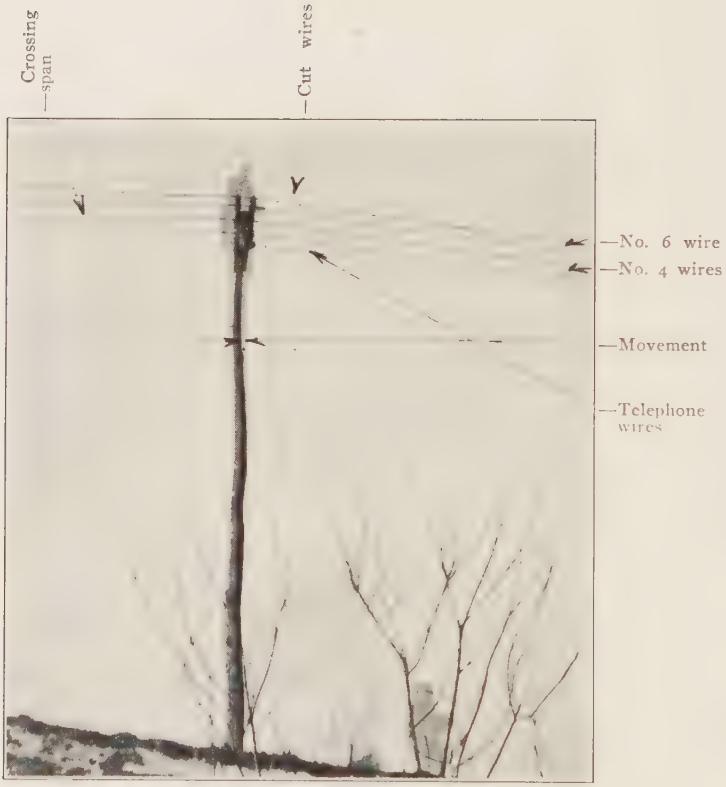
Pole B

Part I—Plate 2

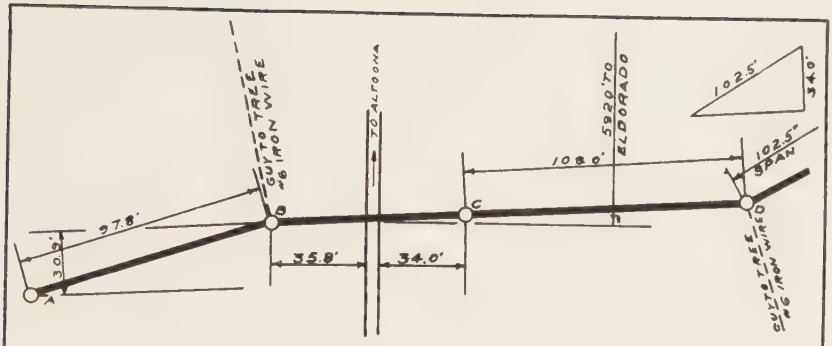
POLE B
TEST I—PLATE 3

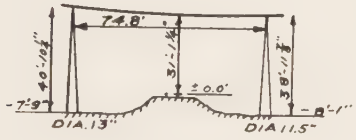


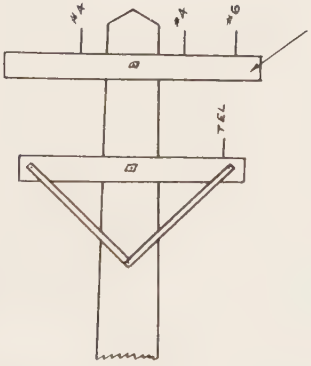
POLE C
TEST 1—PLATE 4



Pole C
Test 1 Plate 5







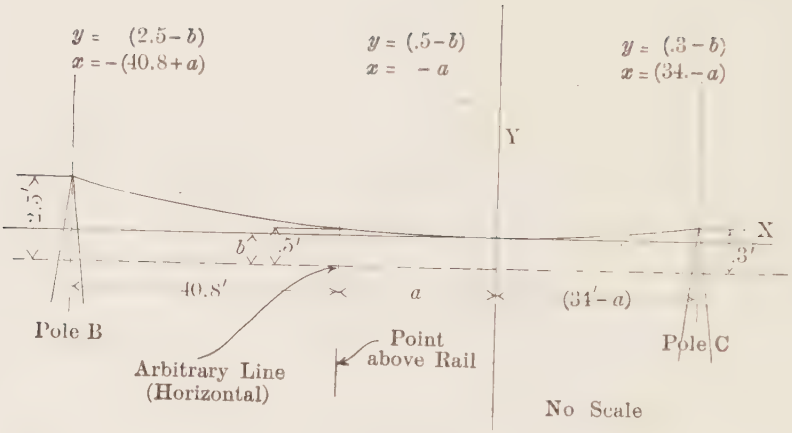
NO SPACING BLOCKS OR BOLTS

ONE NO. 6 AND TWO NO. 4 B.&S. INSULATED WIRES 2300 VOLTS
TWO TELEPHONE WIRES
DOUBLE WOOD ARMS 3½" X 4½" X 4'-0"
4 PINS
DOUBLE GLASS INSULATORS
DOUBLE WOOD PINS
WOOD POLES

POLE C FROM TRACK.

PENN CENTRAL LIGHT & POWER CO.
ELDORADO, PA

130



Sketch Showing Wires Before They Were Cut. Other Sketch Similar. No. Scale

Tension of Wires Cut at the Point 5920 Feet South of Eldorado Station, Hollidaysburg Branch, Middle Division, on February 9, 1912

Given three points (from sketch) on the parabola $\chi^2 = 2\rho\gamma$ ①.

$$\begin{aligned} \gamma &= (2.5 - \beta) \\ \chi &= -(40.8 + a) \end{aligned} \quad [1] \qquad \begin{aligned} \gamma &= (.5 - \beta) \\ \chi &= -a \end{aligned} \quad [2]$$

$$\begin{aligned} \gamma &= (.3 - \beta) \\ \chi &= (34 - a) \end{aligned} \quad [3]$$

A being the distance from the assumed center (or point of measurement) of the span to the correct center and b being the distance from the center of the span to an arbitrary horizontal line:

From equation ① and [2] we have $a^2 = 2\rho\ (.5 - \beta)$ ② and

from [1] we have $\frac{2}{-a - 40.8} = 2\rho\ (2.5 - \beta)$ ③ or

$$a^2 + 81.6\ a + 1662.6 = 2\ \rho\ (2.5 - \beta).$$

By substituting for a^2 its value in ② we have

$$2\ \rho\ (.5 - \beta) + 81.6\ a + 1662.6 = 2\ \rho\ (2.5 - \beta)$$
$$81.6\ a = 2\ \rho\ (2.5 - b - .5 + \beta) - 1662.6$$

$$a = \frac{4\ \rho}{81.6} - \frac{1662.6}{81.6}$$

$$= .049\ \rho - 20.35\ ④$$

From [2] and [3] we have by ①

$$a^2 = 2\ \rho\ (.5 - \beta)\ ②\ \text{and}$$

$$\frac{2}{34 - a} = 2\ \rho\ (.3 - \beta)\ ⑤$$

$$1156 - 68\ a + a^2 = 2\ \rho\ (.3 - \beta)$$

By substituting a^2 from ② in ⑤ we have

$$1156 - 68\ a + 2\ \rho\ (.5 - \beta) = 2\ \rho\ (.3 - \beta)$$
$$-68\ a = 2\ \rho\ (.3 - \beta - .5 + \beta) - 1156$$
$$68\ a = +4\ \rho + 1156$$
$$a = .00588\ \rho + 17\ ⑥$$

Equating ④ and ⑥ we have

$$.049\ \rho - 20.35 = .00588\ \rho + 17.$$
$$.0431\ \rho = 37.35$$
$$\rho = 866.5$$

From ④ a is equal to

$$a = .049 \times 866.5 - 20.35$$
$$= 42.46 - 20.35$$
$$= 22.11$$

From ② substituting $\frac{2}{22.11}$ for a^2 we have

$$\frac{2}{22.11} = 2 \times 866.5 \ (-.5 - \beta)$$

$$488.85 = 866.5 - 1732\ \beta$$

$$\beta = \frac{377.65}{1732} = .2178 \text{ say } .22$$

From the values of α and β we obtain the correct co-ordinates of the three points as follows:

$$\gamma = (2.5 - .22)$$
$$\chi = -(40.8 + 22.11) \quad [1]$$
$$\gamma = 2.28$$
$$\chi = -62.91 \quad [1]$$

$$\gamma = (.5 - .22)$$
$$\chi = -22.11 \quad [2]$$
$$\gamma = .28$$
$$\chi = -22.11' \quad [2]$$

$$\gamma = (.3 - .22)$$
$$\chi = (34 - 22.11) \quad [3]$$
$$\gamma = .08$$
$$\chi = 11.89 \quad [3]$$

Taking [1] as the point to consider, we have a sag of 2.28 feet and an equivalent span of $2 \times \chi$ or 125.82 feet or a ratio

of $\frac{\text{sag}}{\text{span}}$ of $\frac{2.28}{125.82} = .01814$

This corresponds to a tension of 6.85 lbs. per foot of span and per pound of wire per foot, or

Tension $= 6.85 \times 125.82 \times .112 = 96.5$ lbs. for the No. 6 wire and

$6.85 \times 125.82 \times .164 = 141.5$ lbs. for the No. 4 wire.

Taking [3] as the point considered, we have a sag of .08 feet and a span of 2χ or $2 \times 11.89 = 23.78$ feet, or the ratio of

$\frac{\text{sag}}{\text{span}} = \frac{.08}{23.78} = .003365$, which corresponds to a tension of 37 lbs. per foot of span and per pound of wire per foot or

Tension $= 37 \times 23.78 \times .112 = 98.5$ lbs. for the No. 6 wire and

Tension $= 37 \times 23.78 \times .164 = 144.1$ lbs. for the No. 4 wire.

	No. 6	No. 4
By the first point.....	96.5 lbs.	141.5 lbs.
By the second point.....	98.5 lbs.	144.1 lbs.

Tension of Wires After Being Cut at the Point 5920 Feet South of Eldorado Station, Hollidaysburg Branch, Middle Division, on February 9, 1912

We assume that the span remained the same after the wires were cut. This is not theoretically correct, as the sag was increased. The difference in span was not more than six inches, which difference would make no practical difference in the tension of the wires if they were considered to have the same sag.

Given the three points

$$\gamma = (4.5 - \beta) \qquad \chi = -(40.8 + a) \qquad [1]$$

$$\gamma = (.7 - \beta) \qquad \chi = -a \qquad [2]$$

$$\gamma = (2.3 - \beta) \qquad \chi = (34 - a) \qquad [3]$$

Where a is the distance measured horizontally from the assumed center of the span to the correct center, β being the distance measured vertically from an arbitrary line to the vertex of the curve

Taking the general form of $\chi^2 = 2\rho\gamma$ ① as before we have from [2]

$$a^2 = 2\rho\,(.7 - \beta) \text{ ②} \quad \text{and from [1]}$$

$$\overline{-a - 40.8}^{\,2} = 2\rho\,(4.5 - \beta) \text{ ③}$$

$$a^2 + 81.6\,a + 1662.6 = 2\rho\,(4.5 - \beta)$$

Substituting in ③ the value of a^2 in ② we have

$$2\rho\,(.7 - \beta) + 81.6\,a + 1662.6 = 2\rho\,(4.5 - \beta)$$
$$81.6\,a = 2\rho\,(4.5 - \beta - .7 + \beta) - 1662.6$$

$$a = \frac{7.6}{81.6}\,\rho - \frac{1662.6}{81.6}$$

$$= .0931\,\rho - 20.35 \text{ ④}$$

From ①, [2] and [3] we have

$$a^2 = 2\rho\,(.7 - \beta) \text{ ②} \quad \text{and} \quad \overline{34 - a}^{\,2} = 2\rho\,(2.3 - \beta)$$
$$1156 - 68\,a + a^2 = 2\rho\,(2.3 - \beta) \text{ ⑤}$$

Substituting the value of a^2 in ② in ⑤ we have

$$1156 - 68\,a + 2\rho\,(.7 - \beta) = 2\rho\,(2.3 - \beta)$$
$$-68\,a = 2\rho\,(2.3 - \beta - .7 + \beta) - 1156$$

$$a = \frac{1156}{68} - \frac{3.2}{68}\,\rho$$

$$a = 17 - .04705\,\rho \text{ ⑥}$$

Equating ④ and ⑥ we have

$$.0931\,\rho - 20.35 = 17 - .04705\,\rho$$
$$.14015\,\rho = 37.35$$
$$\rho = 266.5$$

Substituting the value of ρ in ④ we have

$$.0931 + 266.5 - 20.35 = a$$
$$24.81 - 20.35 = a$$
$$a = 4.46$$

From ② we have

$$4.46 = 2 \times 266.5 \ (.7 - \beta)^2$$

$$19.89 = 373.1 - 533\ \beta$$

$$\beta = \frac{353.21}{533}$$

$$\beta = .6627, \text{ say } .66$$

The correct ordinates referred to axis passing through the low point of the curve are for [1], [2] and [3]

$$\gamma = (4.5 - .66)$$
$$\chi = -(40.8 + 4.46) \quad [1]$$
$$\gamma = 3.84$$
$$\chi = 45.26 \quad [1]$$

$$\gamma = (.7 - .66)$$
$$\chi = -4.46 \quad [2]$$
$$\gamma = .04$$
$$\chi = -4.46 \quad [2]$$

$$\gamma = (2.3 - .66)$$
$$\chi = (34 - 4.46) \quad [3]$$
$$\gamma = 1.64$$
$$\chi = 29.54 \quad [3]$$

The sag below the high pole [1] was 3.84 feet and the equivalent span was $2\ \chi$ or $2 \times 45.26 = 90.52$. The ratio of

$$\frac{\text{sag}}{\text{span}} = \frac{3.84}{90.52} \text{ or } .0424.$$

This corresponds to a tension of 2.9 lbs. per foot of span and per pound of wire per foot, or tension $= 90.5 \times .112 \times 2.9 = 29.4$ lbs. for the No. 6 wire and $2.9 \times 90.5 \times .164 = 43.1$ lbs. for the No. 4 wire.

Taking the other pole [3] we have a sag of 1.64 feet and an equivalent span of $2 \times 29.54 = 59.08$ feet. The ratio of

$\frac{\text{sag}}{\text{span}} = \frac{1.64}{59.08}$ .02775. This corresponds to a tension of 4.5 lbs. per foot of span and per pound of wire per foot, or the tension $= 4.5 \times 59.1 \times .112 = 29.8$ lbs. for the No. 6 wire and for the No. 4 wire $4.5 \times 59.1 \times .164 = 43.6$ lbs.

	No. 6	No. 4
From first point tension =	29.4 lbs.	43.1 lbs.
From third point tension =	29.8 lbs.	43.6 lbs.
Mean	29.6 lbs.	43.35 lbs.

Fibre stress in base of Pole C.

Total strain on pole

2 No. 4 Wires =	86.7 lbs.
1 No. 6 Wire =	29.6 lbs.
	116.3 lbs.

Height above ground to load = 468 inches

Bending moment = 468 inches $\times$ 116.3 lbs. = 53,428 inch-pounds.

Diameter base = 12 inches.

Section modulus $= .098 \times \frac{3}{12} = 169.4$.

Fibre stress $= \frac{53,428}{169.4} = 315.7$ lbs.

Test No. 2—Southard Street, Trenton, N. J.:

The crossing consisted of two No. 6 copper, 2200-volt weatherproof, insulated wires; two No. 4 copper, 110-volt, weatherproof, insulated wires, and two No. 4 copper, 4000-volt, weatherproof, insulated wires. These wires were held with No. 6 horse-shoe ties, similar to type No. 1 shown on page 449, making three turns around the conductor, to double, deep-groove, double and triple petticoat, glass insulators, on standard 1¼-inch wooden pins. The crossarms were double 3½-inch by 4¼-inch by 8-foot yellow pine equipped with braces and spacing bolts. The poles were chestnut, approximately 11 inches in diameter at the base. The crossing poles and adjoining poles were held together with two ¼-inch stranded galvanized guys; one guy extending from the top of each of the crossing poles to a point approximately 15 feet above the ground on the adjoining pole. A similar guy was installed from the top of the adjoining pole to the crossing pole. Each of these guys had placed in it a General Electric 18-inch wooden strain insulator. (See Plates 6, 7, 8 and 9.)

The construction of this crossing was very good. From an examination of the crossing, it appeared that the guys and a number of the pins had very recently been installed. The height of the wires above the elevation of the rail at pole B was 33 feet 9¼ inches, at pole C 31 feet 5¼ inches, and at a point above the rail 30 feet 9½ inches.

Just prior to cutting the wires a very short exposure was taken of each of the crossing poles with the cameras placed as firmly as possible. The wires were then cut between poles C and D, one at a time beginning with the outside street wire and alternating either side of the center of the arm. As soon as all of the wires were down, another short exposure was taken of each of the crossing poles, on the same negative without changing the camera position. These plates, Nos. 6 and 7, show very little change in sag and hardly any pole movement.

The height of the wires above the rail was again measured and found to be 30 feet 5¾ inches, showing an increase in the sag of 3¾ inches. The ties held without slip of the line wire and no breakage of any kind occurred.

The calculation for the tension of these wires, computed in a manner similar to the previous test, shows that the stress in the wires before being cut was, for the No. 6, 88.2 lbs., and for the No. 4, 129.4 lbs. This tension on the ties was decreased as each additional wire was cut until they were all down. The figures for this condition show the tension for the No. 6 to be 76.2 lbs. and for the No. 4, 115.5 lbs.

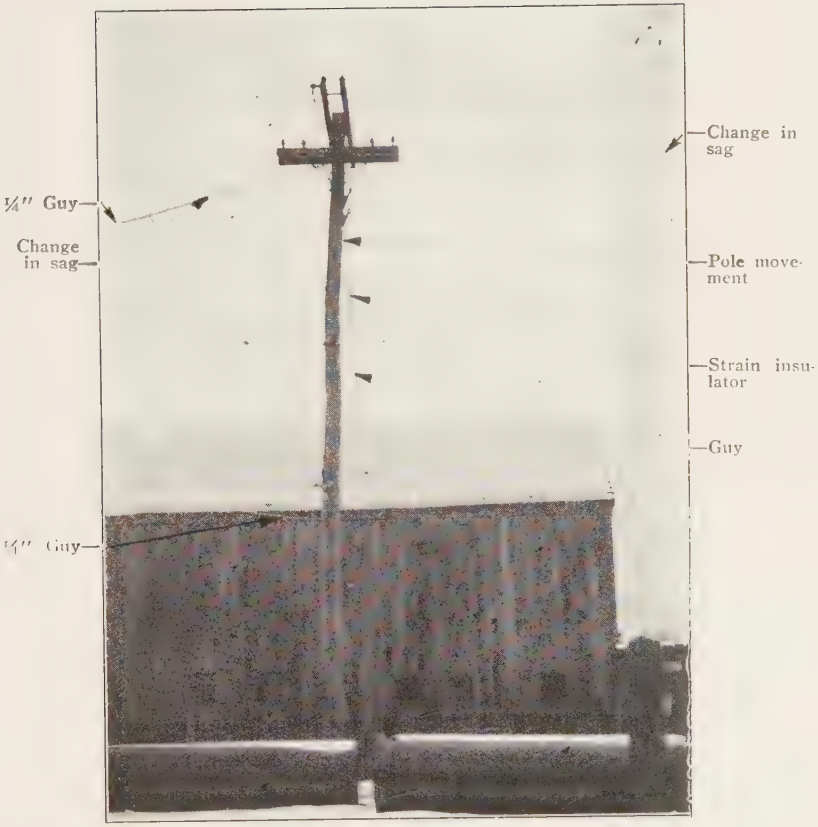
This test also shows that our present standard 2400-volt methods of construction are sufficient for ordinary crossing spans.

Stress in Wires Before Being Cut at Southard Street, Trenton, N. J., March 6, 1912.

Assuming that these wires follow the curve of a parabola of the general form $\chi^2 = 2\rho\gamma$ [1] we have through points i. e.

$$\begin{matrix} \chi = (47.5 - \alpha) \\ \gamma = (3.604 - \beta) \end{matrix} \quad [1] \qquad \begin{matrix} \chi = -\alpha \\ \gamma = (.625 - \beta) \end{matrix} \quad [2]$$

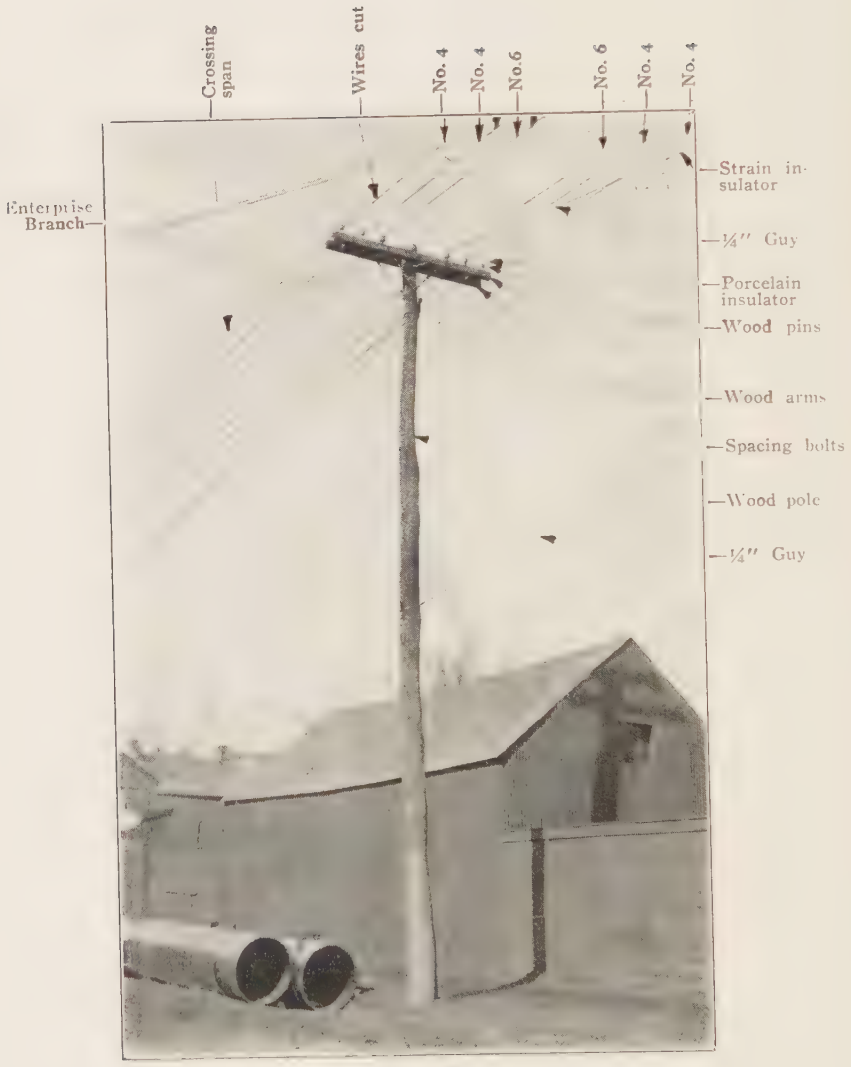
$$\begin{matrix} \chi = (66.3 - \alpha) \\ \gamma = (1.271 - \beta) \end{matrix} \quad [3]$$



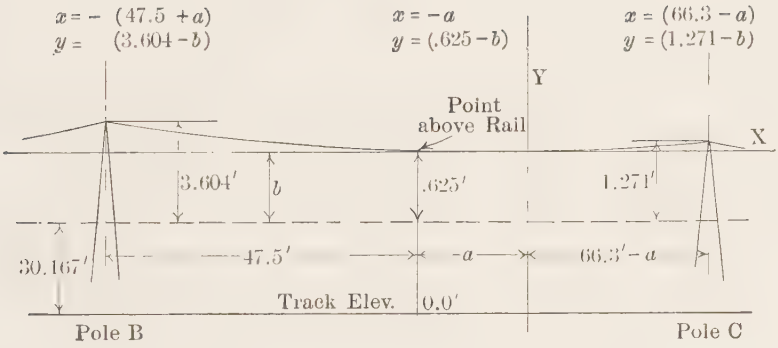
Pole B
Test 2—Plate 6

Pole C
Test 2—Plate 7

Pole B
Test 2—Plate 8



Pole C
Test 2—Plate 9


x = − (47.5 + a)
y = (3.604 − b)
x = − a
y = (.625 − b)
x = (66.3 − a)
y = (1.271 − b)
Y
Point
above Rail
X
3.604′
b
.625′
1.271′
30.167′
47.5′
− a
66.3′ − a
Track Elev. 0.0′
Pole B
Pole C

No Scale

Where a is the distance measured horizontally from the center of the curve to the point above rail, and β is the distance measured vertically from an auxiliary horizontal line to the χ axis.

From the general form of the equation we have for point [2] $a^2 = 2\rho\ (.625 - \beta)$ ② and for point [1] $-(47.5 + a)^2 = 2\rho\ (3.604 - \beta)$ ③; for point [3] we have $(66.3 - a)^2 = 2\rho\ (1.271 - \beta)$ ④

Taking equation ④ we have

$$\overset{2}{66.3} - 132.6\,a + a^2 = 2.542\,\rho - 2\,\rho\,\beta.$$

Substituting the value of a^2 in ③ in the above we have

$$4395.7 - 132.6\,a + 1.25\,\rho - 2\,\rho\,\beta = 2.542\,\rho - 2\,\rho\,\beta$$
$$-132.6\,a = -4395.7 + 1.292\,\rho$$

$$a = \frac{4395.7}{132.6} - \frac{1.292\,\rho}{132.6}$$
$$= 33.15 - .0097\,\rho \quad ⑤$$

Taking equation ③ we have

$$\overset{2}{47.5} + 95\,a + a^2 = 7.208\,\rho - 2\,\rho\,\beta$$

Substituting the value of a^2 in ② in the above we have

$$2256.3 + 95.6 + 1.25\,\rho - 2\,\rho\,\beta = 7.208\,\rho - 2\,\rho\,\beta$$
$$95\,a = 5.958\,\rho - 2256.3$$

$$a = \frac{5.958}{95}\,\rho - \frac{2256.3}{95}$$

$$a = .0627\,\rho - 23.75 \quad ⑥$$

Equating ⑤ and ⑥ we have

$$33.15 - .0097\,\rho = 6.0627\,\rho - 23.75$$
$$-.0724\,\rho = -56.9$$
$$\rho = 785.9$$

From equation ⑤ $3315 - .0097\,\rho = a$ we have

$$a = 33.15 - .0097 \times 785.9$$
$$= 33.15 - 7.62$$
$$= 25.53$$

Substituting the values of a and ρ in ② we have

$$\frac{2}{25.53} = 2 \times 785.9\,(-.625 - \beta)$$

$$651.8 = 982.4 - 1571.8\,\beta$$

$$\beta = \frac{330.6}{1571.8} = .218'\,\beta$$

The co-ordinates of the three points [1], [2], [3] become

$$\chi = -(47.5 + 25.5) \quad [1]$$
$$\gamma = (3.604 - .218) \quad [1]$$
$$\chi = -73.0' \quad [1]$$
$$\gamma = 3.386 \quad [1]$$

$$\chi = -25.5 \quad [2]$$
$$\gamma = (.625 - .218) \quad [2]$$
$$\chi = -25.5 \quad [2]$$
$$\gamma = .407' \quad [2]$$

$$\chi = (66.3 - 25.5) \quad [3]$$
$$\gamma = (1.271 - .218) \quad [3]$$
$$\chi = 40.8 \quad [3]$$
$$\gamma = 1.053 \quad [3]$$

The center of the span is then 40.8 feet and 73 feet, respectively, from the low and high pole.

The sag below the high pole being 3.386 feet with an equivalent span of 2χ or $2 \times 73 = 146$ feet or a ratio of

$$\frac{\text{Sag}}{\text{Span}} \text{ of } \frac{3.386}{146} = .6232$$

or the tension in the wires was 5.4 lbs. per pound of wire and per foot of span or tension is equal to $5.4 \times 146 \times .112 = 88.2$ lbs. for No. 6 wire.

For the No. 4 wire

$$5.4 \times 146 \times .164 = 129.4 \text{ lbs.}$$

	No. 4	No. 6
Tension in wires before being cut...	88.2 lbs.	129.4 lbs.

Tension in Wires in the Crossing Span After They Had Been Cut in the Adjoining Span

On measuring the clearance above the track after the wires had been cut in the adjoining span we found that the sag at the point above the rail had increased 3¾ inches or .3125 foot, say .312 foot. This means that both the χ and the γ axes have changed and it is necessary to solve in the same manner as in the previous case.

The sketch will be the same as before the points, being as follows:

$$\begin{aligned} \chi &= -(47.5 + a) \\ \gamma &= (3.604 - \beta) \end{aligned} \quad [1] \qquad \begin{aligned} \chi &= -a \\ \gamma &= (.313 - \beta) \end{aligned} \quad [2$$

$$\begin{aligned} \chi &= (66.3 - a) \\ \gamma &= (1.271 - \beta) \end{aligned} \quad [3]$$

These points give us the following equations when considered to be on the parabola $\chi^2 = 2\,\rho\,\gamma$.

$$-\overset{2}{(47.5 + \alpha)} = 2\,\rho\,(3.604 - \beta) \quad ③$$

$$-\overset{2}{\alpha} = 2\,\rho\,(.313 - \beta) \quad ⑦$$

$$\overset{2}{66.3 - \alpha} = 2\,\rho\,(1.271 - \beta) \quad ④$$

Taking equation ③

$$-\overset{2}{(47.5 + \alpha)} = 2\,\rho\,(3.604 - \beta)$$

$$2256.3 + 95.\alpha + \alpha^2 = 7.208\,\rho - 2\,\rho\,\beta$$

and substitute the value of α^2 in ⑦ in the above and we have

$$2256.3 + 95.\alpha + .626\,\rho - 2 = 7.208\,\rho - 2\,\rho\,\beta.$$

$$95\,\alpha = 6.582\,\rho - 2256.3$$

$$\alpha = \frac{6.582}{95}\,\rho - \frac{2256.3}{95}$$

$$= .0693\,\rho - 23.74 \quad ⑧$$

Taking equation ④

$$\overset{2}{66.3 - \alpha} = 2\,\rho\,(1.271 - \beta)$$

$$4395.7 - 132.6\,\alpha + \alpha^2 = 2.542\,\rho - 2\,\rho\,\beta$$

and substituting the value of α^2 in ⑦ in the above we have

$$4395.7 - 132.6\,\alpha + .626\,\rho - 2\,\rho\,\beta = 2.542\,\rho - 2\,\rho\,\beta$$

$$-132.6\,\alpha = 1.916\,\rho - 4395.7$$

$$\alpha = -\frac{1.916}{132.6}\,\rho + \frac{4395.7}{132.6}$$

$$\alpha = -.01445\,\rho + 33.15 \quad ⑨$$

Equating ⑧ and ⑨ we have

$$.0693\ \rho - 23.74 = -.01445\ \rho + 33.15$$
$$.0838\ \rho = 56.89$$
$$\rho = 678.8$$

From equation ⑨

$$\alpha = -.01445 \times 678.8 + 33.15$$
$$\alpha = -9.8 + 33.15$$
$$= 23.35$$

Substituting the values of α and ρ in ⑦ we have

$$\overline{23.35} = 2 \times 678.8\ (.313 - \beta)$$
$$545.2 = 424.9 - 1357.6\ \beta$$
$$120.3 = -1357.6\ \beta$$
$$\beta = -\frac{120.3}{1357.6} = -.089$$

The co-ordinates of the three points [1], [2], [3] become, when referred to, the correct axis

$$\chi = -(47.5 + 23.35) \qquad \chi = -23.35'$$
$$\gamma = (3.604 + .089) \qquad [1]\ \gamma = .313 + .089\ [2]$$
$$\chi = -70.8 \qquad [1]\ \chi = -23.35\ [2]$$
$$\gamma = 3.693 \qquad \gamma = .402$$

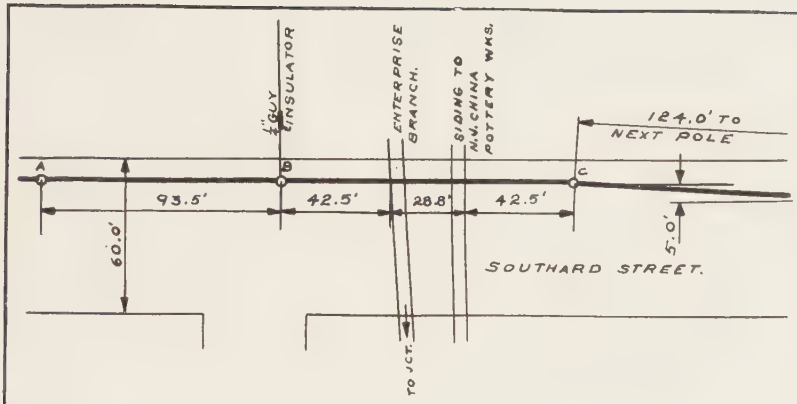
$$\chi = 66.3 - 23.35$$
$$\gamma = 1.271 + .089\ [3]$$
$$\chi = 42.95$$
$$\gamma = 1.36\ [3]$$

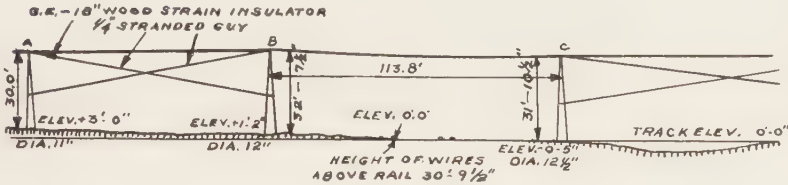
The sag below the high pole is 3.693 feet and the equivalent span is 2×70.8 feet $= 141.6$ feet. The ratio of

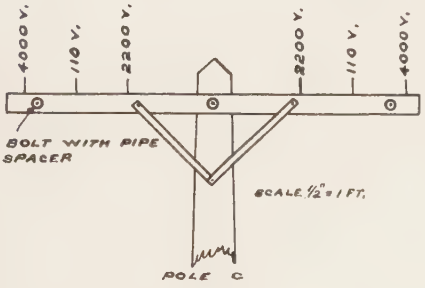
$$\frac{\text{sag}}{\text{span}} = \frac{3.693}{141.6} = .0260.$$

This corresponds to a tension of 4.8 lbs. per pound of wire per foot and per foot of span or tension for the No. 6 wires was $141.6 \times 4.8 \times .112 = 76.2$ lbs., and for the No. 4 wires $141.6 \times 4.8 \times .164 = 111.5$ lbs.

	No. 6	No. 4
Tension after cutting	76.2 lbs.	111.5 lbs.







2 #6 INSULATED WIRES
2200 VOLTS
4 #4 INSULATED WIRES
110 AND 4000 VOLTS
6 HORSE SHOETIES
GLASS INSULATORS, DOUBLE
WOOD PINS, DOUBLE 1 1/4"
WOOD ARMS, DOUBLE 3 1/2" X 4 1/4" X 8'-0" Y.P.
WOOD POLES

NEGATIVES
POLE B 49, 52 AND 55.
POLE C 50, 51, AND 53.

PUBLIC SERVICE ELECTRIC CO.
TRENTON N. J.
SOUTHARD STREET.

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Test No. 3—Baltimore Avenue, Philadelphia, Pa.:

This crossing consisted of six No. 2/0 commercial drawn, stranded, triple braid, 5500-volt copper wires; three No. 6 commercial drawn, solid, triple braid, 2300-volt wires and two No. 6 commercial drawn, solid, triple braid wires for arc service. These wires, with the exception of the arc circuits, were supported on double porcelain insulators, the arc circuits being supported on glass insulators. The No. 2/0 wires were tied with No. 2 bare copper and the No. 6 wires with the line material. All wires were supported on double 1½-inch locust pins, double yellow pine 3⅜-inch by 4⅜-inch by 8-foot crossarms, fitted with spacing blocks and braces, and white chestnut poles 16 inches in diameter at the ground.

The poles were spaced so as to give a crossing span of 120.2 feet with adjoining spans of 94 feet and 125 feet; the crossing and adjoining poles being connected together with 5/16-inch stranded, galvanized, steel cross guys fitted with two Anderson compression, all-porcelain type strain insulators.

The crossing was in excellent condition, the only criticism being that the size of the guys might be considered small for a crossing carrying as much copper as this one does.

The dimensions of the crossing and materials were taken on the 20th, inst., as per Plates 5, 10, 11, 13 and 14 and on the morning of the 21st, inst., the crossing span was loaded with 185 pounds of live load on each of the 2/0 wires, hung at a point approximately midway of the crossing span. This load consisted of two sacks of cement averaging 92.5 pounds each, supported by a rope passed over each individual wire. This load, as applied, is shown on Plates 15 and 16. At the time this negative was taken only a portion of the load had been placed.

As soon as the entire load had been placed the height of the wires was taken above elevation 00 and found to be 53.6 feet. From a parallelogram of forces, this indicates an initial stress in these wires of 1260 pounds each.

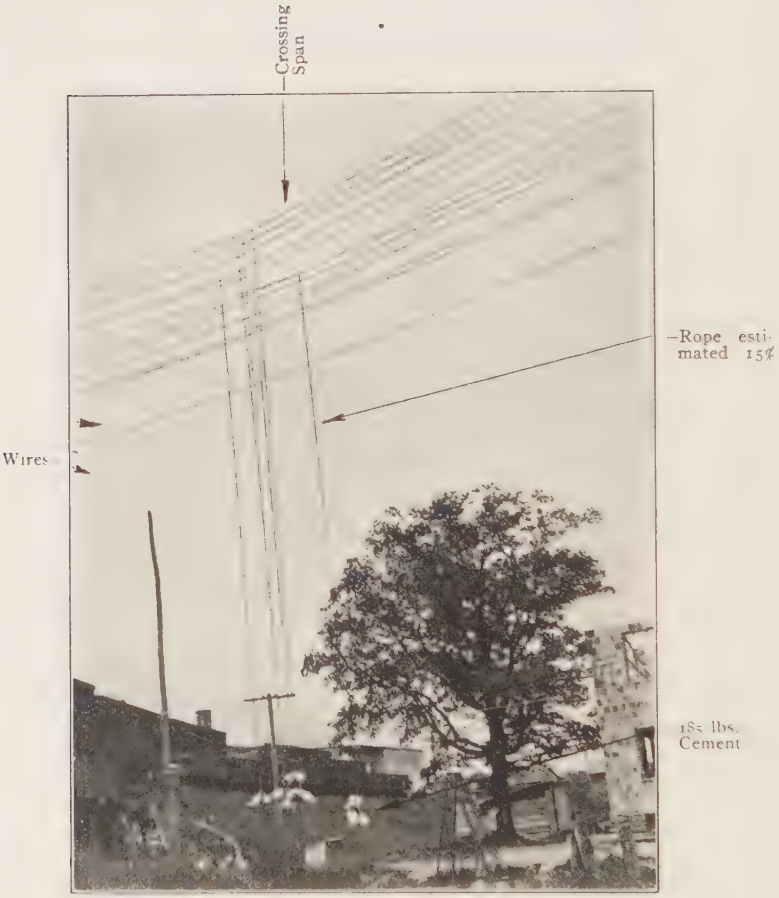
Previous to loading the crossing a very short exposure was taken of the crossing pole in its normal condition and as soon as the total load had been applied a second exposure was taken. The wires were then cut, one at a time, beginning at the outside wire and alternating from one side of the pole to the other, until the six loaded wires were all cut, the point of cut being approxi-

mately four feet from the adjoining pole in the 94-foot span. A measurement was then made of the height of the wires above elevation 00 and found to be 45.1 feet; the weights remaining clear of the ground. The remaining No. 6 wires were then cut, which allowed the weights to drop to a point so that a portion of the load was removed. This condition is shown by Plate No. 16.

As soon as all wires were down a second exposure without movement of the cameras was taken—Plates No. 10 and No. 11 —showing the pole deflected from full load to load with all wires cut, and Plate No. 12 showing the pole deflection from normal condition to loaded condition with all wires cut. Plate No. 12 shows all wires down.

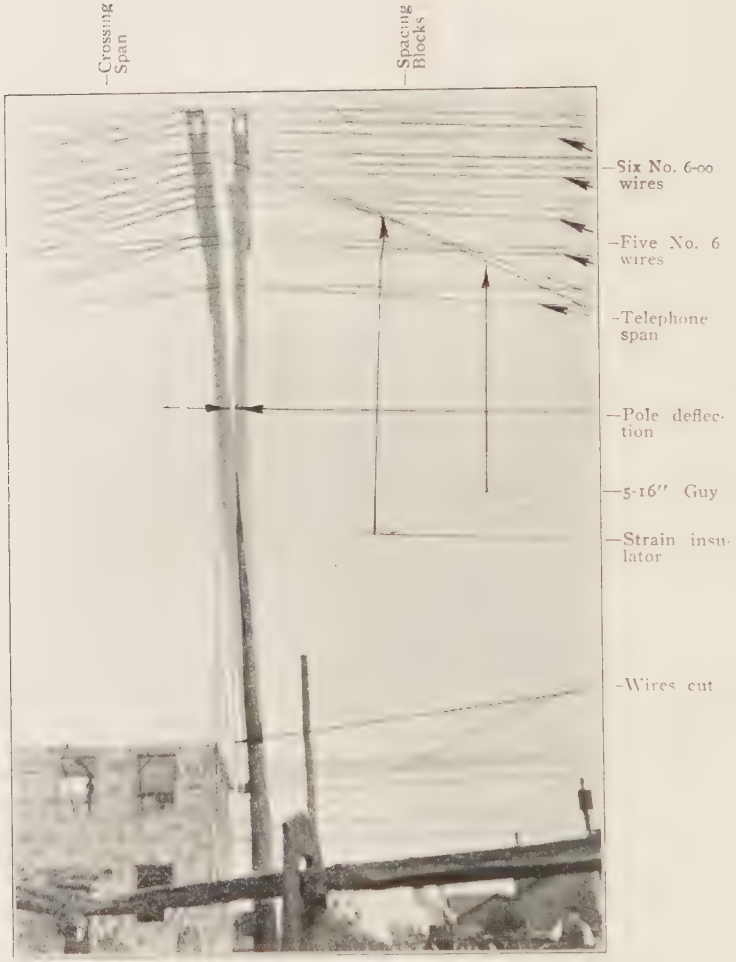
Under the conditions of stress as given above, there was no slip of the line wire at the ties and no breakage of any kind occurred, the only result being pole deflection as shown on the accompanying Plates, with a corresponding decrease of overhead clearance in the crossing span.

It will be noted that in this test the standard work of the Electric Company was sufficient to take the strains imposed upon it at the crossing span.



METHOD OF LOADING
TEST 3—PLATE 16

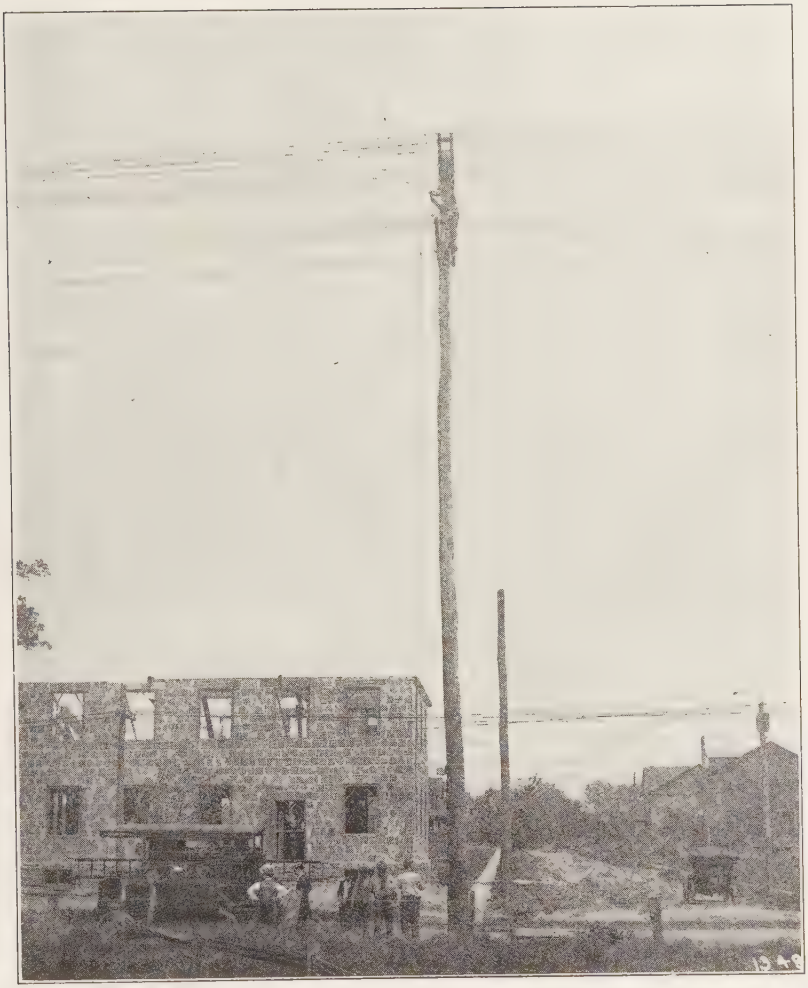
POLE C
TEST 3—PLATE 10



Poll C
Test 3—Plate 11

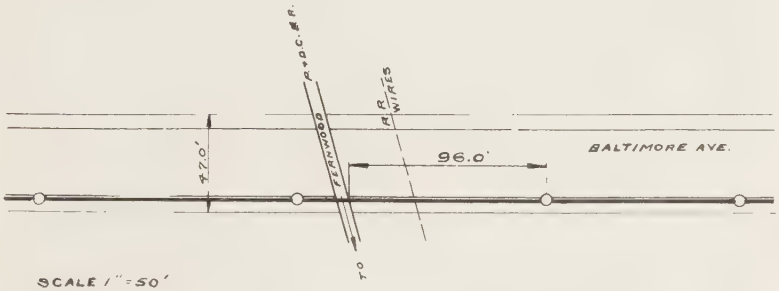
POLE C
TEST 3—PLATE 12

TEST 3—PLATE 13

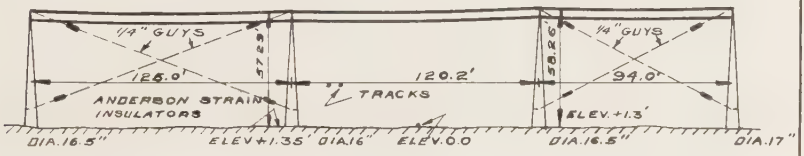


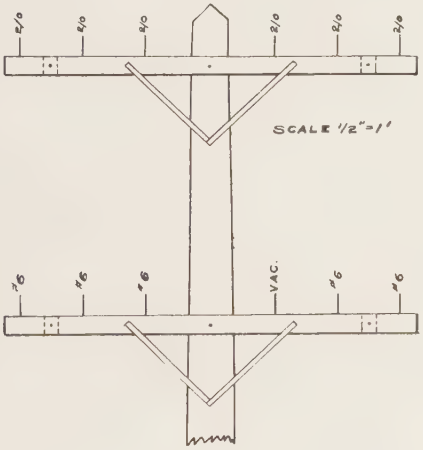
TEST 3—PLATE 14

TEST 3—PLATE 15



SCALE 1"=50'





6 #2/0 - 3 BRAID WIRES.
5500 VOLTS.
PORCELAIN INSULATORS DOU
#2 BARE WIRE TIES.
LOCUST PINS, 1.5", DOUBLE.
WOOD ARMS, 3 3/8" x 4 3/8", DOUBLE.
3 #6-3 BRAID WIRES
2300 VOLTS
INSULATORS, PINS, AND ARMS
AS ABOVE
2 #6-3 BRAID WIRES
ARC CIRCUIT
GLASS INSULATORS.
WOOD POLES

PHILADELPHIA ELECTRIC Co.
FERNWOOD, PA

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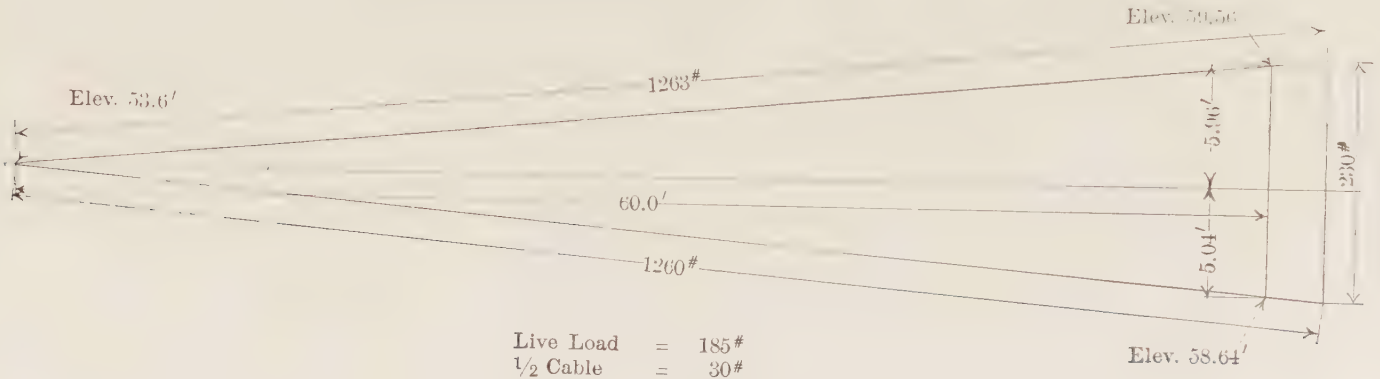
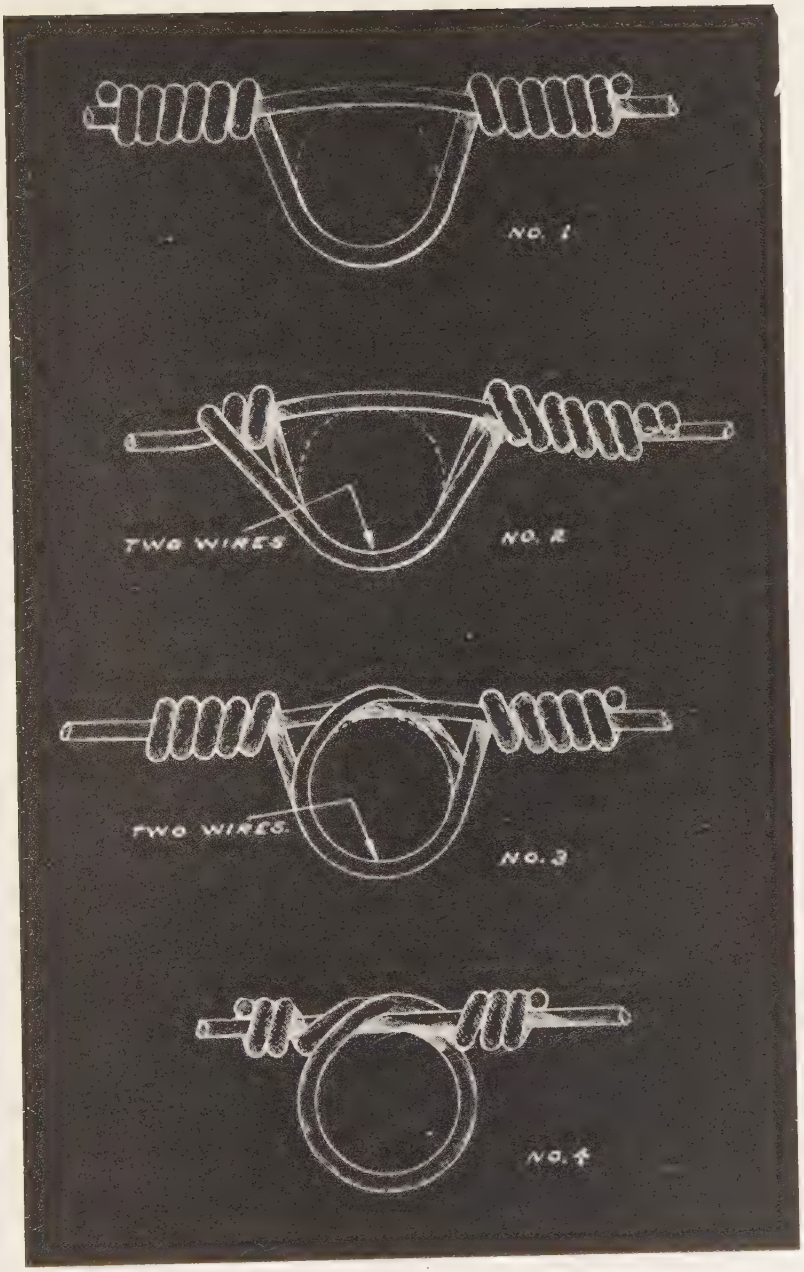


Live Load	=	185#
½ Cable	=	30#
Rope (est.)	=	15#
Total	=	230#



Railroad Crossing Ties

Test No. 4—Winfield Avenue, Philadelphia, Pa.:

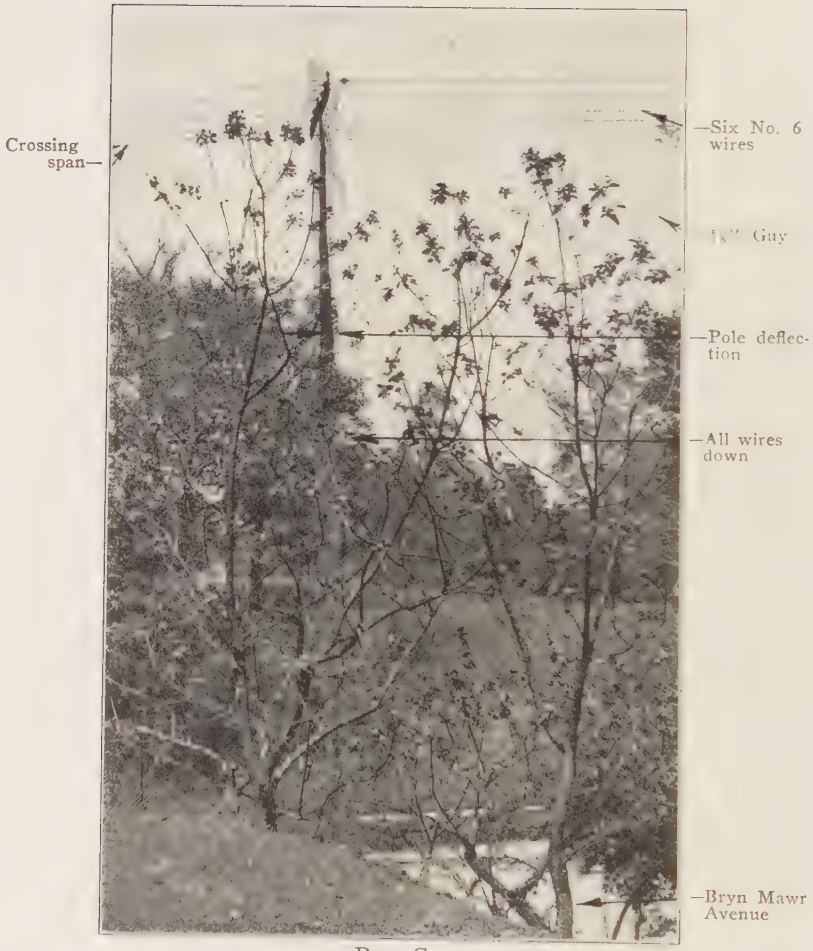
At this crossing the wires were supported by double glass insulators, double horseshoe ties of the line material, similar to those shown on page 449, type No. 1 double 1½-inch locust pins, double yellow pine 3⅜-inch by 4⅜ inch by 8-foot crossarms fitted with spacing blocks, and braces and white chestnut poles 18 inches in diameter at the ground line. The crossing poles were spaced to give a crossing span of 131 feet with adjoining spans of 125 feet and 133.5 feet. These dimensions, as well as height, etc., are given on plate No. 18.

Each of the crossing wires was loaded individually with 92.5 pounds suspended by ropes in the crossing span above a point 46 feet from the east-side crossing pole and directly above elevation 00. This load brought the wires down to a point 40.6 feet above elevation 00 and caused a stress of 303 pounds per wire.

Previous to loading this crossing a short exposure was taken on plates Nos. 19 and 20 of the east-side crossing pole. The wires were then cut in the east-side adjoining span at a point approximately four feet from the east-side adjoining pole. This resulted in a .4-foot decrease of height of the wires above elevation 00. No breakage of any kind occurred nor did the wires slip at the ties.

This test also shows that standard construction is sufficient for crossing work.

Method of Loading Wires
Test 4—Plate 17



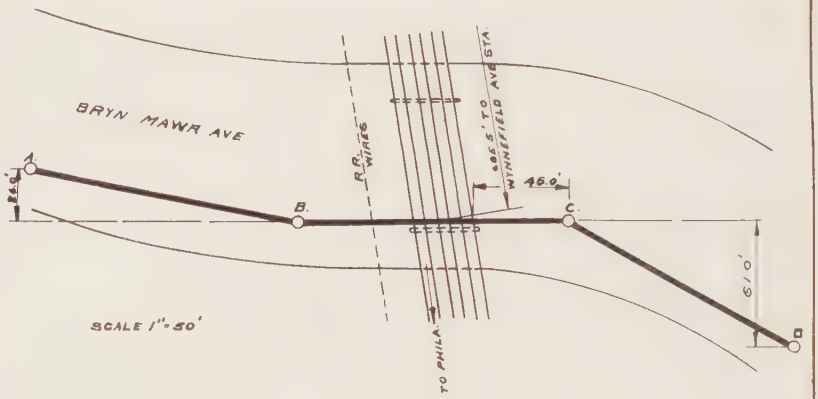
POLE C

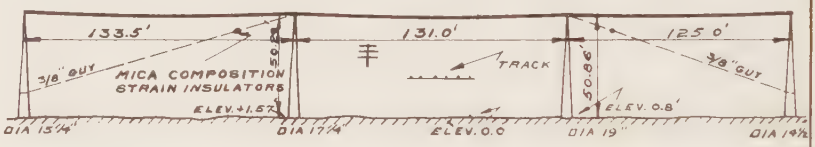
TEST 4—PLATE 18

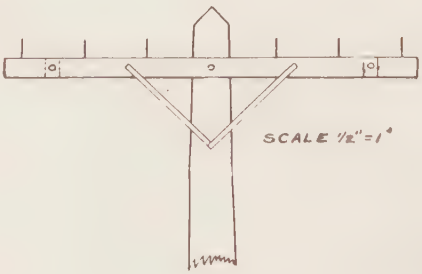
Showing Pole Movement
Test 4—Plate 19

Showing Pole Movement
Test 4—Plate 20

Method of Loading
Test 4—Plate 21







6 #6-3 BRAID WIRES
ARC CIRCUIT
GLASS INSULATORS, DOUBLE.
#6 HORSESHOE TIES
WOOD PINS 1½"-DOUBLE.
WOOD CROSS ARMS 3 3/8" X 4 3/8" DOU.
BRACES AND BLOCKS
WOOD POLES

PHILADELPHIA ELECTRIC Co
WYNNEFIELD AVE., PA.

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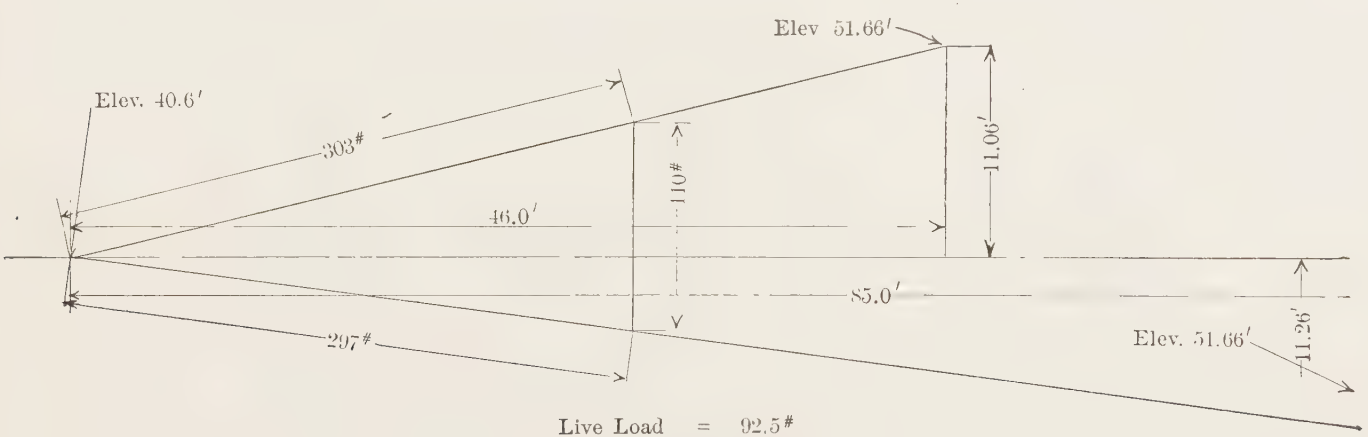


Live Load	=	92.5#
1/2 Wire	=	7.3#
Rope (est.)	=	10.2#
Total	=	110.0#

Test No. 5—Altoona, Pa.:

The crossing consisted of two No. 6, 110-volt insulated wires, supported on single porcelain insulators, single No. 6 horseshoe ties, making two turns around the line wire, single 1¼-inch wooden pins and single yellow pine six-pin arms 3¼-inch by 4¼-inch by 7 feet, equipped with braces and supported on wooden poles.

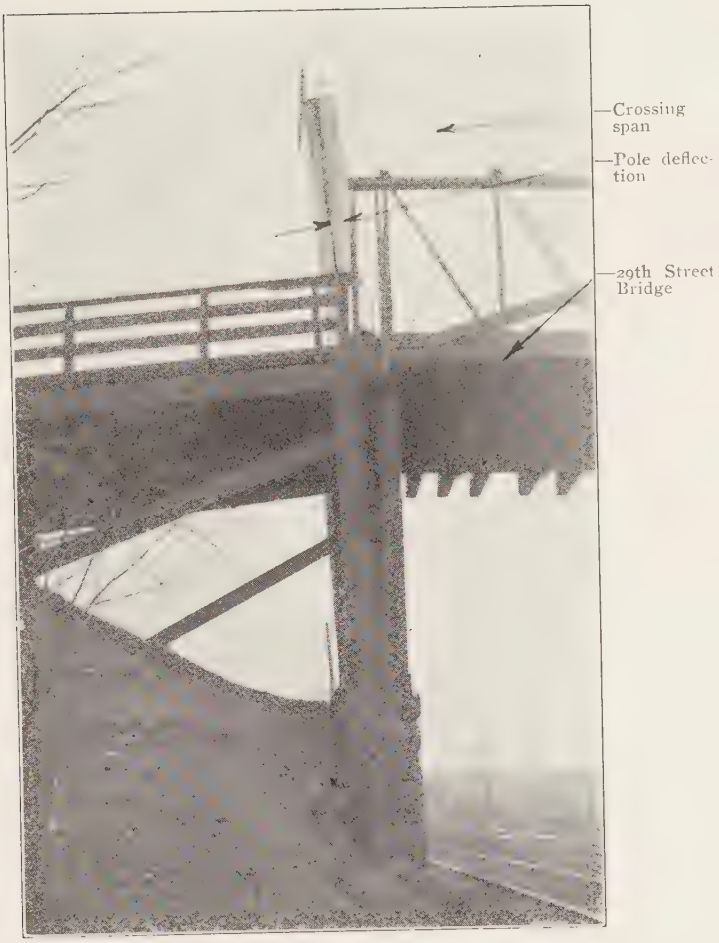
Each of these wires was loaded with 90 pounds at a point midway between the crossing poles, which is shown on plate No. 25. This weight pulled the north wire down to a point 24.94 feet above elevation 0.0, and the other wire down to the point 26.19 feet above elevation 0.0. The wires were then cut at a point in the adjoining span near the west-side adjoining pole. As soon as each wire was cut the weights immediately dropped to the ground, the wires slipping through the ties. The initial stress on these wires before being cut is shown, by a stress diagram, to be for the north-side wire 330 pounds and for the other wire 288 pounds.

The condition of the ties after cut was made is shown, for the west-side pole, on plate No. 22, and for the east-side pole, on plate No. 24. Plates No. 23 and 26 show very *clearly that the ties were not suitably installed.*

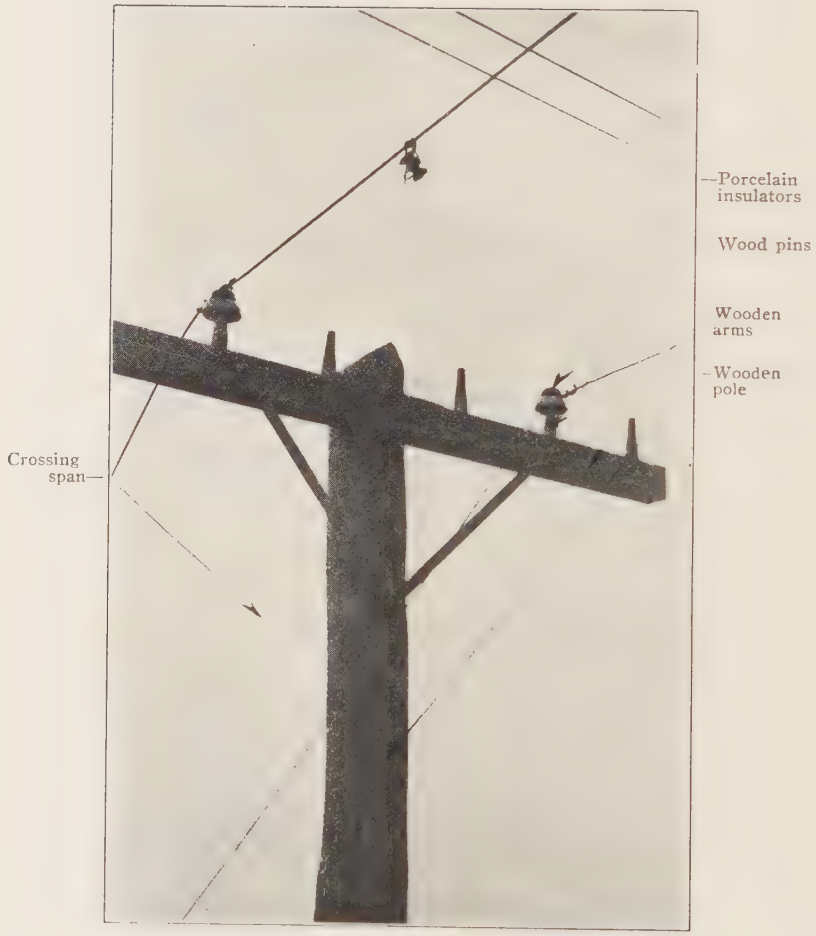
These four successful tests, combined with the one test which, in confirmation of expectations, failed, we believe, to be sufficient evidence of the lack of necessity for special devices for the tying of wires for crossings of normal span lengths when the construction is done in accordance with Section 1 of the 1911 Committee Report, which deals with 2400-volt work.

The fact that the tests were made on the lines of several companies in different sections, bringing out the variations in methods of construction which necessarily occur among different groups of construction men, we believe warrants us in placing on record, as we did to-day, our interpretation of 2400-volt crossing requirements. Special tying devices should not be demanded.

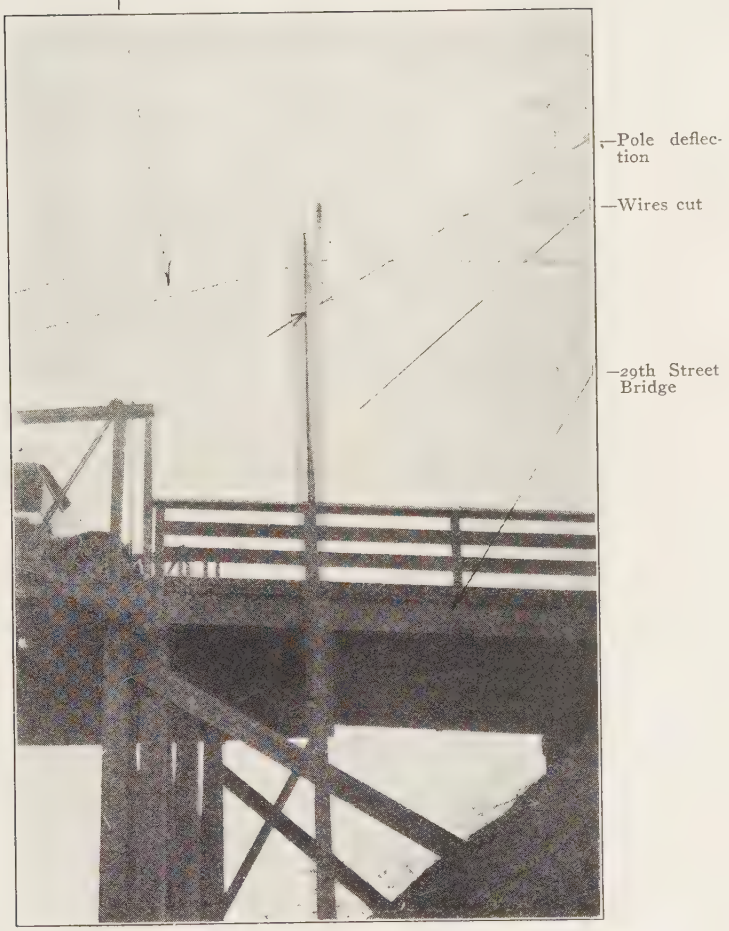
In conclusion, I want to offer a resolution for the joint committee, for the reason that we have now made a change in our specifications in Section 18, which we have just passed. Your committee feels, therefore, that it would be well to ask the General Session to approve our specification again this year, with this change included and emphasized so that no one can come



West Side Pole
Test 5—Plate 22

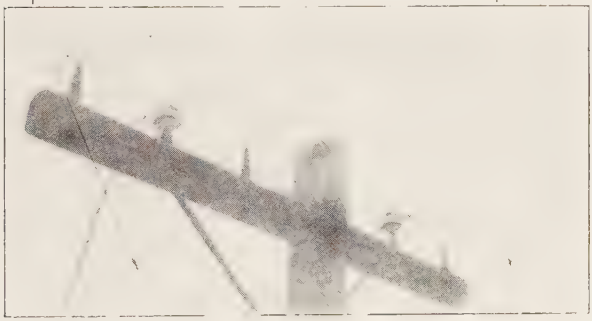


East Side Pole
Test 5—Plate 23

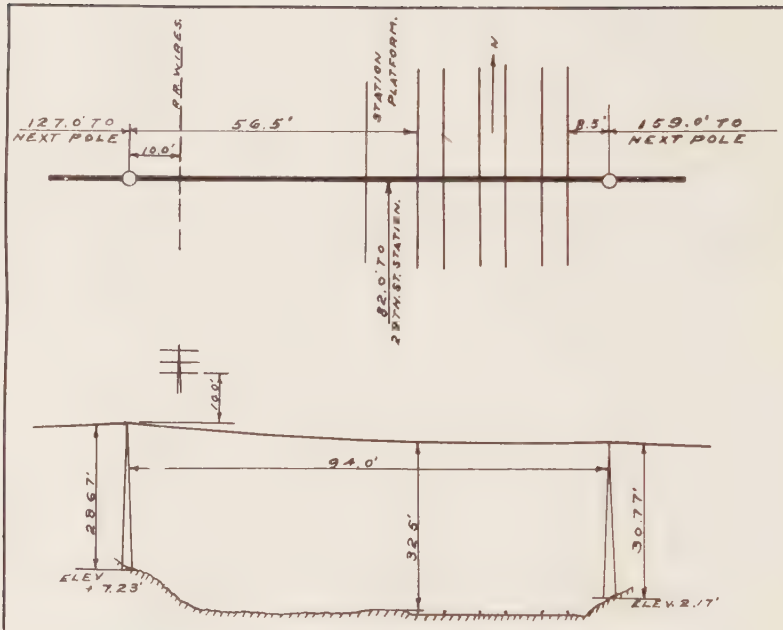


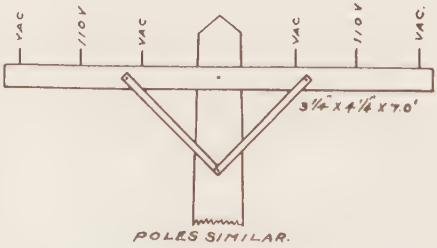
East Side Pole
Test 5—Plate 24

Method of Loading
Test 5—Plate 25



West Side Pole
Test 5—Plate 26





2 #6 INSULATED WIRES
110 VOLTS
PORCELAIN INSULATORS
#6 HORSE SHOE TIES
WOOD PINS SINGLE
WOOD ARMS SINGLE
WOOD POLES.

PENN CENTRAL LIGHT & POWER CO
ALTOONA, PA. 29TH. ST.

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back to us and say we have not finished up the work. We offer the following: "Resolved, That the Technical Session recommend to the General Session that it approve the overhead line-construction specifications, including the changes adopted to-day."

The motion was thereupon put to vote and unanimously carried.

(Adjourned.)

THIRD TECHNICAL SESSION

THURSDAY MORNING, JUNE 13

THE CHAIRMAN, PRESIDENT JOHN F. GILCHRIST: The first item of business is the report of the Committee on Prime Movers, Mr. I. E. Moultrop, Boston, Chairman.

Mr. J. B. Klumpp, of Philadelphia, will read the report.

ABSTRACT OF REPORT

WATER POWER

The relative merits of vertical *vs.* horizontal units are discussed. Reference is made to the subject of the pitting of water-wheels. Testing of water-wheels in place is recommended, with some suggestions as to the method to be used. Governors and safety devices to prevent runaways are mentioned. The subjects of relief-valves and stand-pipes are treated mainly by reference to articles in engineering societies' transactions. Brief mention is made of materials for penstocks, and, under the head of measuring water, a very interesting device is described which is suitable for moderate flows. The advantages of storage reservoirs are discussed as well as the subject of steam-power auxiliaries for water-power plants, including a reference to a novel form of steam-power relay station. Ice troubles are briefly mentioned.

STEAM POWER

Some recommendations are given for the purchase of coal on an ash basis. Mention is made of a boiler installation of unusual-sized units. Mechanical stokers and steam-flow meters are discussed at some length, and mention is made of feed-water regulators and troubles with feed-water piping due to the pitting of the interior of the pipe. Some extended notes are given on the use of cast iron in connection with superheated steam. A brief mention is made of a new type of boiler using the principle of surface combustion, as well as of some of the new forms of high-efficiency reciprocating steam units which are being exploited abroad. The development of the steam turbine during the past year is described, and reports received from several manufacturers are briefly stated. Some discussion is given on the performance of condensers with reference to the economical vacuum point, and reference is also made to the life of condenser tubes. Moisture in exhaust steam from the prime mover is discussed with some suggestions as to the methods of determining the quantity, and a brief mention is made of a reduction gear for adapting the high-speed turbine to the work calling for slower speeds.

GAS POWER

Condensed statistics from the United States Government reports are given, showing approximately the existing status of fuel oil supply; also oil specifications for fuel adapted to the different types of engines. The primary features of the oil engines are described and a list of builders given. Results from oil-engine plants, including operating costs, are given along with some experience of individual operators. Report is made of the progress of the practical development of an oil producer for power or fuel gas, and reference is also made to some of the principal improvements in gas-engine design during the past year. Development in the coal-gas producer during the year is briefly mentioned, and a short description is given of the unique Humphreys gas pump, together with a scheme for its application to a steam-generating station. Mention is also made of the possibility of utilizing waste heat from internal combustion engines. A brief mention is also made of the gas turbine and the alcohol engine. Reference is made to some interesting literature on the general subject of gas power.

REPORT OF THE PRIME MOVERS COMMITTEE

Your Prime Movers Committee for this year has in general continued the work of the previous Committee. Careful consideration has been given to the discussion of last year's Report, and the suggestions contained therein have been followed so far as seemed expedient. Much thought has been given to the subject of water power, and, as this form of energy is used so extensively in that portion of our country where this report is to be presented and discussed, this subject is given first place in the report.

The progress of steam-power development during the past year is treated in a concise manner, and special attention has been given to the various appurtenances of the steam plant.

The gas power section of this report has been extended to embrace all forms of prime movers using either liquid or gaseous fuels in the cylinder of the prime mover.

WATER POWER

The water-power section of this report is practically a continuation of last year's report. Owing to the extreme breadth of the subject and the fact that each installation seems to be a special problem in itself, it has been possible to treat it in a very general manner only.

Your Committee hopes that the members interested in water power, and especially our western members, will discuss and criticize this report freely. Such discussion will also be of much assistance to the next Committee.

TURBINES

Vertical vs. *Horizontal Units*

The principal conditions favorable to the use of the vertical type of water-wheel are:

First.—Where the head is so low that there is insufficient room between the head and tail water levels to allow the water to be properly supplied to and carried away from the wheel.

Second.—Where the saving in floor space by the use of the vertical type will permit a reduction in the cost of the station building.

Excessive variation in the height of backwater introduces the same objections to the use of the vertical wheel as low head.

As against these two advantages there are so many disadvantages in the use of vertical units that it is rare to find an operating man who is in favor of this type. Particularly is this true when it is borne in mind that the horizontal type does away with the necessity of an expensive and troublesome step or thrust bearing and its resulting auxiliary apparatus, such as oil-pressure pumps, piping, etc. In the vertical type of unit the thrust of the water may be utilized to a certain extent in overcoming the weight of the revolving element, but this thrust is variable and depends upon the load on the unit, so that the thrust bearing must be designed to take care satisfactorily of the entire weight of the revolving element.

Considerable success has resulted recently in the use of roller bearing thrusts for vertical units of large size, and this type of bearing, if successful, promises to reduce to a minimum the troubles which have heretofore been met with. Such bearings are now installed carrying a total load of 400,000 pounds, and have the further advantage over oil or water-pressure thrusts of being more accessible for repairs, and can even be operated for considerable periods of time without a fresh supply of oil. The principal difficulty in their use has been in obtaining steel roller plates of metal which is uniformly hard and able to withstand the severe service.

Vertical units, as a rule, mean that the operating force at the station must be divided between at least two different floors or levels, which tends to increase the cost of operation. The horizontal unit is more accessible for repairs, and the turbine may be dismantled with little or no interference with the electrical generator and *vice versa*.

Pitting

Your Committee feels that the last year's report covering this heading is worth repeating: "Comparatively little trouble is reported with the runners, with the exception of pitting or scoring. Various causes are assigned to this, but, undoubtedly, the principal one is poor inherent design, sometimes augmented by foreign matter in the water. This effect is usually noticed on the backs of blades. If blades are correctly designed for the

conditions under which the wheel is to operate, there should be little trouble on this score, although it is likely to make its appearance where wheels are operated over long periods of time at partial gate opening, which has a tendency to change the relative direction of flow of water to the angle of the blades."

Water-wheel builders of standing will ordinarily guarantee their wheels against pitting. However, there seems to be some question as to the relative merits of bronze, cast-iron and steel for runners, and your Committee recommends further investigation of this question of material.

Testing of Water-Wheels in Place

Two methods are available:

First.—If the water-wheel and electric generator comprise an individual unit, the unit as a whole may be used for the test, absorbing the output of the generator by means of artificial load (water, rheostat, etc.). In this method the losses incident to the generator must be segregated. If the turbine and generator are separate, self-contained units, each having its own bearings and connected either through a shaft coupling, by belting or by other means, the inaccuracies in using this method will be minimized.

Electrical generators of small or medium size up to approximately 2000-kw are usually given factory tests, by which not only their electrical losses are determined, but the bearing and windage as well. It should be understood that all such efficiencies shall be as complete as practicable, including load losses. These shop tests are, as a rule, fairly accurate, and, unless serious changes in conditions have taken place in shipment, they may be safely used in tests made after installation. It should be pointed out, however, that, unless the electrical generators have been tested under actual load conditions, there may be considerable variation in the final results. For instance, efficiencies based on iron and copper losses by laboratory measurement made with the machine at rest may differ considerably from the same efficiencies obtained under actual running conditions.

For vertical units, and particularly those in which the generator is not, strictly speaking, self-contained, that is, has only one individual bearing, it is difficult to separate the mechanical losses of the generator from those of the turbine.

In these cases the final turbine efficiencies as found in test may be affected by approximately 1 per cent or more.

SECOND.—Some form of dynamic brake may be used to determine the mechanical output of the turbine. In small units up to 100 hp the ordinary form of prony brake may be employed and when properly handled will give fairly accurate results. An interesting development for such mechanical testing of larger units is described in the paper entitled "The Testing of Water-wheels After Installation," by Prof. C. M. Allen, of Worcester Polytechnic Institute, Worcester, Mass., and presented before The American Society of Mechanical Engineers. This paper may be found on page 275 of Volume XXXII of the Society's Transactions for the year 1910.

The following description is quoted from Prof. Allen's paper:

> "The Alden Absorption Dynamometer has been developed and built in large sizes. It is a form of prony brake and usually consists of several smooth circular, revolvable, cast-iron discs keyed to the shaft which transmits the power; a non-revolvable housing having its bearing upon the hubs of the revolving discs; and a pair of thin copper plates in contact with each cast-iron disc, the plates being integral with the housing. Through a system of piping, water under pressure is circulated through chambers between the units, each consisting of a disc and its copper plates, and between the outer plate at either end and the wall of the housing. The water pressure is regulated by hand or by an automatic valve. Another system of piping circulates oil for lubricating the surface of the copper plates next to the revolving discs. In the large-sized machines, oil, impelled by a belt-driven pump mounted on the housing, enters the chamber at the circumference and is forced along the radial grooves of the disc to the hub, and completes its circuit through hose connections to the pump.
>
> The power required to drive the pump is measured with, and included in, the power of the dynamometer, for the pump is bolted to the housing, and the driving tension in the belt which operates the pump tends to rotate the housing in the same manner as does the internal friction of the discs; this makes a calibration to determine power used by the oil-pump unnecessary.
>
> When the dynamometer is in use, the water passes through the chambers of the housing and between the several units of plates and discs, and by its pressure tends

to force the plates against the sides of the revolving discs. This pressure increases the friction between the discs and plates, and this friction offers resistance to the rotation of the discs. The construction resembles that of a constantly slipping friction disc clutch. The resistance to turning imposed by the friction plates and discs is balanced by the weighing apparatus."

At the suggestion of Prof. Allen, your Committee communicated with nine firms and individuals who had experience in the use of this interesting testing device, and without exception their replies were favorable to its use. It has been stated that the results obtained by this method of testing have been accepted by all parties interested in such tests, without exception.

The largest unit tested by this method, of which your Committee has learned, was 4000 hp, but Prof. Allen states that there is no reason why this dynamometer cannot be constructed to test units up to 10,000 hp. The cost of making tests by this method has been stated to vary from approximately $200 for units of 500 hp to $1000 for testing 5000-hp machines. It must be understood that these cost figures are but approximate, and are given only as indicating the cost of testing in this way as compared with other means.

Your Committee most strongly recommends the practice of making tests periodically on water-wheel-driven units in addition to the initial tests upon installation. Wherever feasible, means should be provided so that these tests can be made by the regular operating force, with whatever reasonable assistance may be necessary, and should always be made with the units in operating condition. Such routine tests are a reliable indication of the condition of the unit. Many tests have been reported, the results of which have been of doubtful value, on account of the extreme preparations taken regarding the prime mover to insure obtaining the highest possible efficiencies, whereas the operating company is more interested in results obtained during the course of routine operation.

GOVERNORS

Your Committee has endeavored to obtain accurate information in regard to the relative amounts of power necessary for driving governor oil-pressure pumps in the open and closed systems. While some small success has followed our efforts in

this respect, it is difficult to make an accurate comparison, for the reason that so few individual plants are using both types of governor on the same sized main units and under similar operating conditions.

In one plant the two types of governors were installed on wheels of identical size and serving the same load. The pumps on the closed-system governors required 4.36 hp, as against 5.56 hp for those supplying the open system. While the difference is small, it must be remembered that the pumps on the closed system, when the governor is not called upon to operate, for some little time require only sufficient power to overcome friction, whereas those in the open system require continually the same amount of power, whether the governor is operating or not. The best comparison between the two pumping systems would be on the basis of the horse-power hours required by each, but these figures your Committee was not able to obtain.

There seems to be no doubt that with the open system a cheaper grade of oil can be used than with the closed system. Many companies report using the same oil in their open-governor systems as is used for general lubricating purposes, whereas most of the closed systems require specially refined oils, in order that they may not break down under the atomizing effect to which the oil may be subjected by leakage through the pump valves to the vacuum chamber.

Your Committee has received information which would indicate that maintenance charges are considerably lower on governors using the open system than on those using the closed system.

As regards first cost, the open-system governors are in general slightly cheaper. Usually local conditions will have a considerable bearing on the choice of the system to be used.

Governors for Impulse Wheels

In the discussion of your Committee's report, presented before the Convention in New York in 1911, mention was made of a governor employing both needle and deflecting nozzles. This governor moves the deflecting nozzle quickly for regulating the speed of the wheel and follows this movement by a readjustment of the needle nozzle, thus wasting the minimum quantity of water. While slightly more expensive than the ordinary

form, it is particularly advantageous where economy of water is a consideration, and should be capable of giving as close speed regulation as any of the present types.

Safety Devices to Prevent Runaway

The numerous instances of deranged governor mechanism causing the water-wheels to attain dangerously high speeds make it advisable to provide effective means for preventing this.

One type of governor is in use which actuates the water-wheel gates by two opposing cylinders, one containing water under constant penstock pressure and having a tendency to close the gates, the other being supplied with oil under varying pressures from the governor. It will be evident that any failure of the governor by which the supply of oil is reduced will have a tendency to close the water-wheel gates; but, in case the relay valve of the governor sticks in such a position as to allow full oil pressure to the cylinder, the device is of little value. It is of value only in plants operating under comparatively high heads, as otherwise the size of the water cylinders becomes cumbersome, and it is not available on double-acting governors, where oil pressure is used to both open and close the gates.

One other device, made by the Lombard Governor Company, has been developed for this purpose, consisting of a separate centrifugal ball-head which, at a pre-determined speed, releases a trigger device admitting oil under full tank pressure behind a piston, which in turn operates the closing side of the governor relay valve. This device will close the water-wheel gates when excessive speed is attained, with the governor itself out of adjustment or broken, provided there is oil pressure in the supply tank and that the piping between it and the governor cylinder is intact.

Your Committee believes there is room for considerable improvement in such safety devices.

RELIEF VALVES

A paper entitled "Speed Regulation in Hydro-Electric Plants," by W. F. Uhl, appears in the *Journal of The American Society of Mechanical Engineers* for February, 1911. This paper covers very thoroughly the various questions suggested by its title, including that of relief valves, and your Committee recommends a careful reading of it for more detailed information.

Mention may also be made of the following articles on the same subject:

"Hydraulic Safety Valves," by Edward Mueller, in *Zeitschrift des Vereines Deutcher Ingenieure,* Berlin, December 25, 1909.

"Pressure Fluctuation in Turbine Pipe Lines," by Prof. A. Budan, in *Journal of the Association of Engineering Societies,* Boston, October, 1908.

STAND-PIPES

Here, again, your Committee merely refers to the following articles, without attempting to go into the matter more deeply:

"The Surge Tank in Water-Power Plants," by R. D. Johnson, in *Transactions of American Society of Mechanical Engineers,* 1908.

"The Surge Tank," by C. Hutzelsieder, in *Zeitschrift fur das Gesamte Turbinenwesen,* Munich, January 10, 1911.

"The Stand-pipe in Water-Power Plants," by Irving P. Church, Cornell, Civil Engineer, October, 1909.

"A Note on the Design of Surge Tanks," *Schweizerische Bauzeitung,* Zurich, January 30, 1909.

"Hydraulic Accumulators in Power Plants," by Arthur Budan, *Zeitschrift des Oesterreichischen Ingenieure und Architekten Vereines,* Vienna, March 12, 1908.

"Safety Devices for Pressure Conduits in Turbine Plants," *Zeitschrift fur des Gesamte Turbinenwesen,* Munich, December 30, 1907.

"Surge Tank Problems," Franz Prasil, *Schweizerische Bauzeitung,* Zurich, November 21, 1908.

Your Committee recognizes that the above references to relief valves and stand-pipes may be disappointing, but it desires to point out that the wisdom of using either or both of these devices must be treated as a special engineering problem in each particular case.

PENSTOCKS.

Three materials have generally been used for this purpose—steel, wood and concrete.

It is hardly possible to make any general recommendations as to the choice of these three materials, as local conditions will very largely govern. In general, where free from erosive action, of excessive velocity of flow, or from erosion or chemical action due to foreign matter in the water, it may be said that a properly constructed, reinforced, concrete penstock should have an almost indefinite life.

Wood-stave pipes have been in successful use for a number of years. Your Committee has learned of a penstock of this material which was installed in 1874 and is still in use. This pipe was 6 ft. in diameter and was made of Georgia pine staves 4 in. in thickness. The most effective means for preserving wood pipe is to bury it, or to adopt other means to keep it continually wet and without extreme temperature changes.

Steel penstocks are generally recognized as the best, first cost aside. Where used with water containing foreign material in suspension or having an acid reaction, erosion or corrosion is likely to take place unless the interior of the pipe is carefully watched and an efficient protective paint is used. It is also important to protect the outside of the steel pipe where buried in the ground, which can be done by painting or by encasing it in concrete.

In general, it may be said that, under average conditions, wood-stave pipes are the cheapest, reinforced concrete and steel following in the order named, the latter being the most expensive.

MEASUREMENT OF WATER

The methods used for determining the quantities of water taken by a turbine or other prime mover are:

First.—By weir.

Second.—By current meter.

Third.—By Pitot tube.

The method used must largely depend upon circumstances. It is considered by the majority of engineers that measurements by weir can be made more accurately than by the other methods named, the current meter or float coming next in accuracy and the Pitot tube last.

A very interesting device for measurement of water is shown in Figure 1 (received from Mr. Hugh L. Cooper), based on the invention of Prof. Erik Anderson, of Stockholm. The device

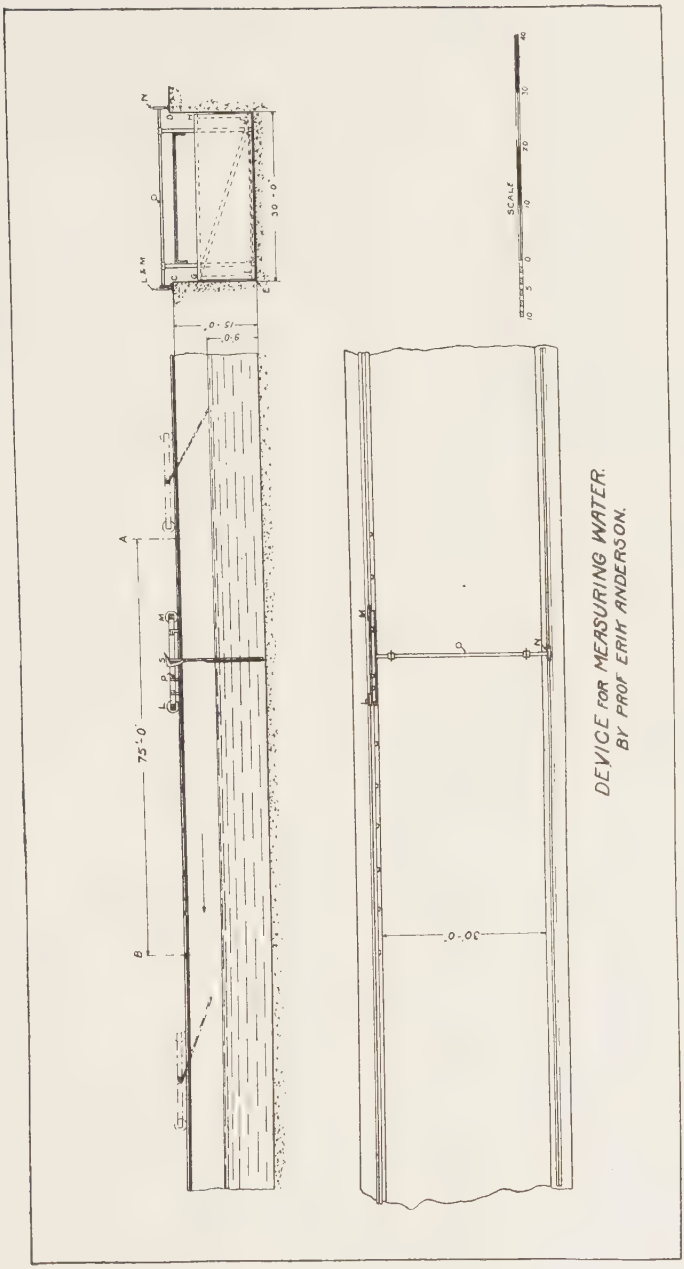

SCALE
30-0
75-0
30-0
DEVICE FOR MEASURING WATER.
BY PROF ERIK ANDERSON.

FIG 1

shown is suitable for flows varying from 540 cu. sec. ft. to 2000 cu. sec. ft. The following description will make clear the principles involved:

> The frame G, H, I, J is a piece of water-proof canvas laid over as light a piece of framework as can be designed to hold the canvas square and tight.
>
> This canvas is carried on a framework that is suspended to the truck L, M, N. The wheel N should be without flanges. The track that the wheels L, M, N use should preferably be steel angles, so that it could be installed perfectly true to line and grade. The bearings for the wheels L, M and N should, for very careful work, be ball bearings, in order to reduce the amount of resistance necessary to drag the car. The distance A, D, 75 feet, shown in this sketch, is, of course, an arbitrary selection, and the car should be started in a flume of this sort, probably 25 feet above the point A, in order that the velocity might have a chance to equalize and take hold normally of the canvas.
>
> At P a contact could be made, and broken at A and B to give the exact time required for the car to travel between A and B. After the car has passed below B the canvas can be lifted by hand and carried back for the purpose of repeating the measurement, the canvas being hinged at point S to provide for this operation.
>
> If any given measurement was required to be theoretically exact, the amount of energy required to overcome the inertia of the truck L, M, N would have to be considered, but in any standard measurement this correction would be too small to be of any practical value and would ordinarily be around a tenth of one per cent of error, which is too fine for this work.
>
> In a measurement of this kind the canal section C, D, E, F should be practically smooth, and practically true to line and grade, and should be straight not only for the distance A, B, but for at least an equal distance above and below the station A, B, in order that the cross section whose velocity is being measured may be as nearly uniform as practicable.
>
> In a close measurement it would be necessary to take the elevation of the water-surface under point A and under point B, and possibly at two intermediate points, with a hook-gauge, in order to secure an accurate cross-section of the water being measured; and the average of these cross-sections so taken would be used into the velocity determined for the ascertaining of the actual quantity moving.

The average of six experiments of the above description would give as close a decision as to the quantity of water as could be obtained by any method other than the actual pouring of water into a tank and measuring its quantity in that way.

The cross-section shown should handle water at velocities from 2 ft. per second up to 8 ft. per second.

STORAGE RESERVOIRS

With the wider use of water power and the further knowledge gained by experience, the increase in value of water storage for equalizing the flow of streams throughout the year is rapidly becoming recognized. The economic question will enter here very largely, it being obvious that no considerable amount of money can be judiciously expended in the construction of storage reservoirs under average conditions unless the head available at the plant is considerable. This question must be largely determined by local conditions surrounding each individual development. Such matters as available locations for storage, cost of development, seasonal variation in river flow and value of power, as well as the all-important one of head, must receive due consideration.

Your Committee desires to point out in connection with this subject that a given quantity of stored water will have a widely varying effect in raising the minimum stream flow, according to the program of development of storage. For instance, a given quantity of stored water properly introduced into the stream will raise its minimum flow a certain definite amount. With the further building of storage reservoirs, the same quantity of water will have less effect in raising the then minimum, because its use will have to be distributed throughout a longer period of time in the year.

This may be illustrated by the diagram, Figure 2, which represents a typical hydrograph or river-flow curve. It will be noted that the minimum flow shown by this curve is 470 cu. sec. ft. The introduction of 100 sq. mi. ft. of stored water will raise the minimum flow to 1100 cu. sec. ft., a difference of 630 cu. sec. ft. If now further stored water in units of 100 sq. mi. ft. is introduced, the figure clearly shows the decreasing amount by which the minimum flow is increased.

It is to be distinctly understood that the above discussion applies solely to the minimum rate of stream flow, and does

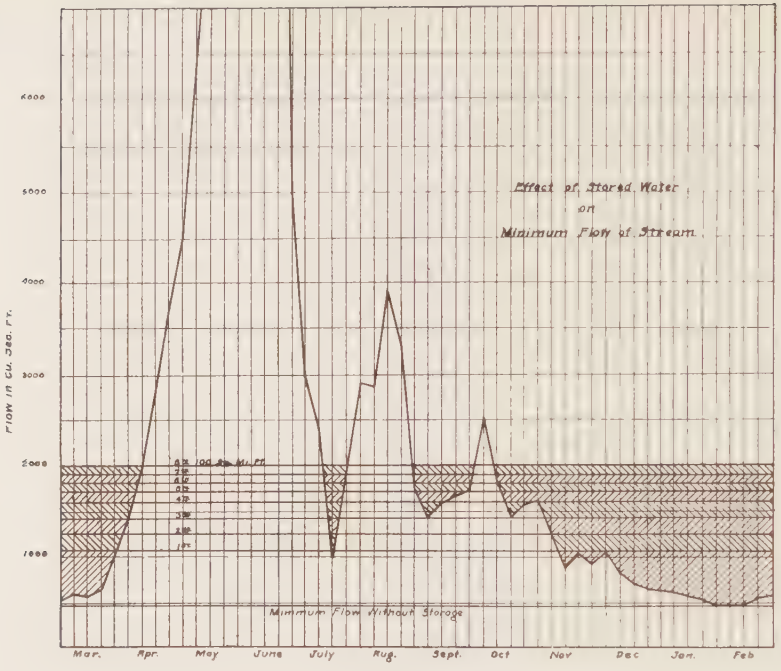

Effect of Stored Water
on
Minimum Flow of Stream
Flow in Cu. Sec. Ft.
6000
5000
4000
3000
2000
1000
Minimum Flow Without Storage
Mar.
Apr.
May
June
July
Aug.
Sept.
Oct
Nov
Dec
Jan.
Feb

FIG. 2

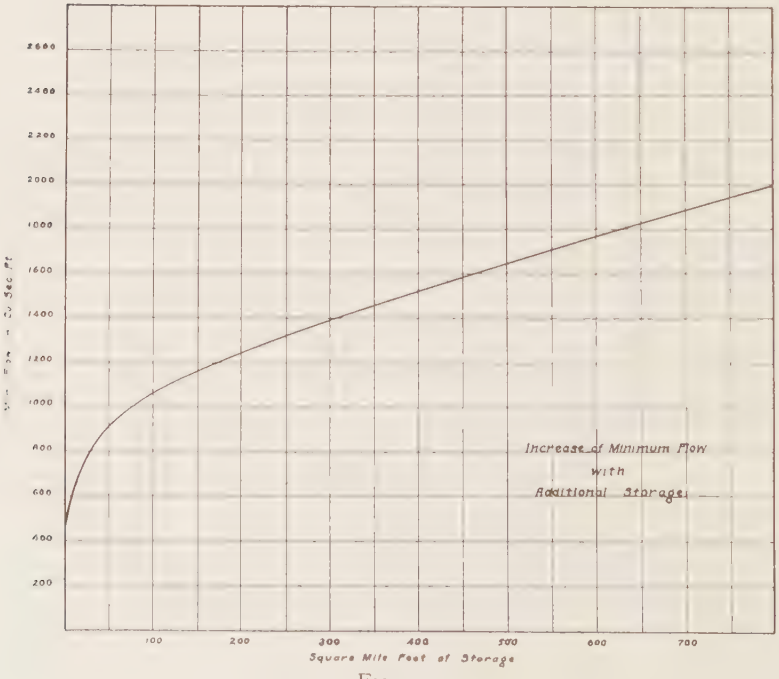

2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
Increase of Minimum Flow
with
Additional Storage
100
200
300
400
500
600
700
Square Mile Feet of Storage

FIG. 3

not mean a proportionately lower volume of water available for power production.

This decrease in minimum flow increment is shown on the curve, Figure 3, which carries the stored water up to 800 sq. mi. ft., resulting, in this particular instance, in the minimum flow of 2000 cu. sec. ft., as against 470 cu. sec. ft. without storage.

Various units are in use for expressing large quantities of stored water, notably the acre foot, square mile foot and cubic foot. Your Committee considers it advisable that some definite unit become standard throughout the country, and, for the purpose of crystalizing ideas on the subject, proposes the adoption of the "square mile foot," which is equivalent to 27,878,400 cu. ft., or 640 acre feet.

STEAM POWER AUXILIARIES FOR WATER-POWER PLANTS

The function of the auxiliary steam plant may be threefold:

1. To act as a stand-by plant to protect the service against interruption in the case of transmission from a distant source of supply.

2. To increase the output of the water-power plant during times of low stream-flow or excessive backwater.

3. To permit the water-power plant to operate under a higher load-factor by carrying the daily peak of the load by steam, especially where sufficient equalizing pondage is not available at the water-power plant.

Used as Stand-by

Numerous means have been tried for making these auxiliary plants effective as insurance against interruption. It is obvious that, whatever method is used, the steam plant must be placed in commission within the shortest time possible after the interruption occurs, and the efforts of various companies to provide this emergency service at the minimum continuing cost have been described from time to time in the technical press. Hot-water storage, oil fuel, powdered coal and other means have been used with varying success for providing the requisite steam pressure in the boilers. It may be said that for emergency service, where interruptions are not likely to be frequent, steam plants showing the minimum first cost are the most desirable. In many

cases where hydro-electric energy has displaced steam generating stations the latter have been retained as relay plants. This is the most advantageous means of providing auxiliary power, but plants so displaced in growing communities very soon become inadequate in capacity for the entire load, but may be useful as partial protection.

Your Committee endeavored to ascertain the approximate cost of maintaining steam auxiliaries, but it is obvious that differing conditions, frequency of interruptions and other items enter so largely that comparisons of kilowatt-hour costs for such plants would be of little or no value unless full details regarding yearly output, number of hours during the year the plant was operated, etc., were taken account of.

A Proposed Stand-by Station

In regard to the above, reference is made to the excellent paper of Mr. A. M. Hunt on the subject of "Emergency Generating Stations in Connection with Hydro-electric Plants," read before one of the San Francisco meetings of the American Institute of Electrical Engineers in 1910. (See 1910 *Proceedings American Institute of Electrical Engineers.*) It is of interest to embody the following abstract:

> Mr. Hunt's scheme for equipping a steam-turbine station and its operation on an emergency call is especially interesting. The boilers are to be oil-fired, the oil and steam supply for the burners is to be controlled from a central point, and igniters are to be fitted in the furnaces which can be operated from a central point so that the fires can be started under all the boilers simultaneously. In addition to the boiler equipment there would be a heat storage, consisting of heavy, vertical, steel tanks containing water at a temperature equal to that of steam at 200-lb. pressure, these tanks being thoroughly protected by heat-insulating material. The water and steam space of these tanks is to be connected with the boilers by automatic stop-valves which will open whenever the pressure in the boilers is greater than in the heat-storage tanks. In the heat-storage tanks will be installed electric heaters having capacity sufficient to maintain the desired temperature of the water, or, in other words, to supply the heat losses from radiation and convection. The capacity of these heat-storage tanks is to be such that sufficient steam will be formed to operate the plant at full capacity for thirty minutes with a reduction of the pressure from

200 lbs. to 25 lbs. The charging of the heat storage tanks is to be accomplished by the use of steam from the main boilers.

In comparing the initial cost of such a plant with a gas-power installation, Mr. Hunt arrives at the conclusion that the steam-turbine station cost would be approximately 46 per cent of that of the gas-power station, and that the stand-by charges on the former should be less than 46 per cent of those for the latter. Mr. Hunt also concludes that the steam-turbine plant constructed with the heat storage as above described can be put on the line as promptly as the gas-engine station, and he considers that within less than two minutes after an emergency call the station should be ready to pick up the load.

Used as Supplement During Water-Power Shortages

The function of the auxiliary plant, when used as supplemental capacity during low-water periods, is similar to that of the storage reservoir described above. It converts at least a part of the secondary power, which is available only part of the year, into primary power available at all times, increasing its sale value. It is also of value in making-up shortage of water power from loss of head during high backwater caused by floods, ice jams or other obstructions below the plant, or loss of head from tides in plants on tide-water.

Used as Supplement During Daily Peaks

The function of the auxiliary plant used to carry the daily peaks of load on the system is similar to that of pondage above the water-power plant, increasing the operating load-factor and consequently the output from water. In the case of the supplemental plant, the first cost and relative economy of generation must be governed by the proportion of the total output of the system to be carried by the auxiliary plant, *i. e.*, the higher the percentage carried by the auxiliary plant, the more important becomes the economy of generation and the less important the first cost and resulting fixed charges.

A number of operating companies maintain one or more steam units in service continuously, keeping these on the line in parallel with the water-power plants. In this connection, your Committee desires to point out that, under these conditions, material assistance may be given to the speed regulation and

power-factors by means of the usually closer governing of modern steam units as compared with water-wheels. This method also insures minimum interruption in the event of failure of the hydro-electric plant or transmission line.

ICE TROUBLES

In extreme climates and where it is impracticable to reduce the entering velocity of water to a sufficient extent to allow the surface to freeze over, and where considerable quantities of anchor or frazil ice are likely to be swept against the racks, adherence to the racks may be reduced either by maintaining the portion of the racks above the water surface at a temperature above freezing by housing or otherwise, or by constructing the exposed portions of the racks of wood, concrete or other non-conductors of heat, the portion below the water being of steel. Electric heaters have been used in some cases for the purpose of preventing clogging of the racks, and it has also been proposed to so arrange the bars composing the rack that a low-voltage electric current may be sent through them in series, thus heating them sufficiently to prevent the adherence of ice.

In order to prevent trouble from ice in the wheel casings, it is essential that effective water-seals be provided in the tail-race discharge to prevent the entrance of cold air.

STEAM POWER

No marked development in steam prime movers has taken place during the past year. Improvements in turbines toward the ends of better economy and facility of repairs have been made. While the larger pieces of apparatus are being standardized, more thought and care is being given to the minor appurtenances of the station. The detailed findings of your Committee follow herewith:

PURCHASE OF COAL ON AN ASH BASIS

The principal impurities in coal are nitrogen, water and ash, all of which may be present in independently varying quantities. From this it would appear that any system of evaluating coal which considers the variation of only one of its three impurities must lead to erroneous conclusions, and while such assumption is correct in general, it is nevertheless true that the method of estimating coal values by ash content alone has, within certain

limitations, decided advantages over the calorimeter method. This is because coal from any particular vein is reasonably constant in its nitrogen and moisture content, however widely its ash may vary; and, moreover, different samples of coal from the same vein vary in commercial value in an inverse but much greater ratio than their variation in ash.

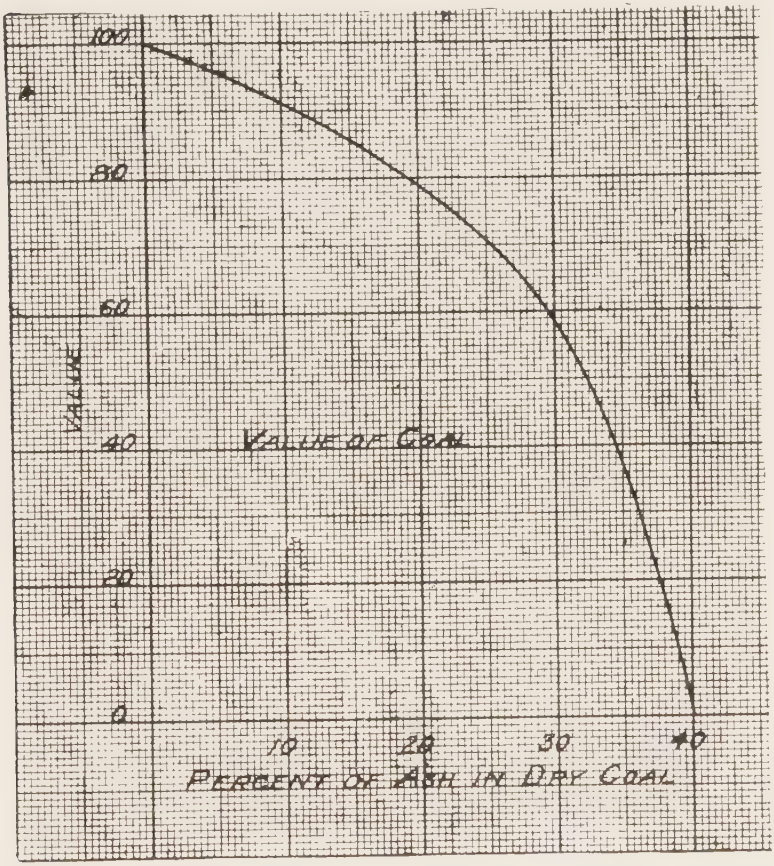


FIG. 4

It has been found in one series of tests reported in the *Journal of the Western Society of Engineers,* September, 1906, that coal containing 40 per cent of ash will not generate high-pressure steam when burned in a boiler furnace. Its value is,

therefore, nil, yet a calorimeter test would indicate that such a sample of coal has a value equal to 60 per cent of that which a sample entirely free from ash would have. From this it is apparent that a formula which evaluates coal in inverse proportion to its ash content (as for example, Value = 100% — % ash) will give erroneous results.

Assuming that coal containing 40 per cent of ash has no value as fuel, and assuming that the rate of decrease of value is constant as the amount of ash increases, the value of a coal for varying amounts of ash would be represented by the formula: Value = 100% — 2½ × % ash. But, as the ratio of fuel values to ash content is not a straight line but a curve (see Figure 4), decreasing slowly at first and falling off rapidly for ash quantities greater than 30 per cent, a formula to represent the entire range would be quite an involved expression; but, as coal containing more than 30 per cent is rarely used, and as the curve for 5 per cent ash to 30 per cent ash is nearly a straight line, it can with a fair degree of accuracy be represented within the range mentioned by the formula: Value = 100% — 1½ × % ash, which is a formula easy to remember and easy to apply and is much more accurate than the formula: Value = 100% — % ash.

In the excellent paper by L. P. Crecelius entitled "The Purchase of Bituminous Coal under B.t.u. Specifications," which appeared in the *Report of the Committee on Power Generation*, which was presented at the 1911 Convention of the American Electric Railway Enginering Association, the author says:

> "The presence of an excessive amount of ash in any coal manifests itself in the nature of a reduction of capacity, because of its occuping a relatively large amount of effective grate area with inert matter. It is also a source of additional expense in the matter of cost of removal and extra wear and tear on ash-handling apparatus. It should, therefore, be restricted to a certain limited amount, no premium being allowed for a minimum. Penalties for amounts in excess of the allowable limit should be provided, and these preferably should become excessive after a certain value. The reason for this is principally that the amount of ash is in a measure the key to the nature of the coal, and the principal purpose of any coal specification should be to provide a steady and uniform supply of fuel, previously determined upon as best suited to existing plant conditions and to limit all other grades of coal."

This clearly indicates that the author realizes that penalties in direct proportion to the amount of ash would be inadequate to protect the consumer, and that deductions from a price fixed for a standard quality of coal should be in a greater ratio than any increase in amount of ash.

BOILERS OF LARGE SIZE

During the past year The Edison Illuminating Company of Detroit has completed the installation of unusually large-sized Sterling type boilers in the Delray plant, and subjected them to a series of very elaborate and extensive tests, the results of which have been reported in recent engineering literature, from which the following conclusions are drawn:

The very high efficiency (80 per cent) which was reached may be attributed in part to the relatively small amount of enclosing-wall surface with a proportionally small amount of radiation and air infiltration, but it is undoubtedly due in greater degree to the carefully selected fuel used, to the performance of the stokers and to the great care and skill employed in the tests, than to the design and size of the boilers.

A brick or tile-roofed furnace producing flue gas having a content of 15 per cent CO_2 would be at a temperature higher than that at which the most refractory fire-clay would melt. Therefore, such high efficiencies and CO_2 percentages are permissible only where the heat of the furnace may be kept down by direct radiation to exposed boiler surface, and, to avoid an objectionable amount of smoke, this in turn requires a very long or high combustion chamber, so that the gases will not come in contact with the boiler surface until the flame has burned out.

It appears, therefore, that those responsible for the Delray boiler have at once demonstrated the practicability of boilers of much larger sizes than anything heretofore attempted, and have combined in the design features which would produce indifferent results in boilers of standard sizes, but which in the Delray size gives capacities and efficiencies among the best recorded in the annals of boiler practice.

Following are comparisons of some of the essential dimensions of the Delray boilers with similar dimensions of the Bab-

cock and Wilcox boilers recently installed in the Northwest Station of the Commonwealth Edison Company:

	Delray	Northwest
Heating surface, sq. ft.	23,650	5,600
Floor area of setting, sq. ft.	795	280
Height, in feet, above floor	39	28
Grate surface, sq. ft.	425	115
Heating surface per sq. ft. grate surface	55	48
Heating surface per sq. ft. floor area	30	20

For full details regarding this large boiler and its test performance reference is made to the paper presented at the December, 1911, meeting of the American Society of Mechanical Engineers, by Dr. D. S. Jacobus. This paper is published in the *Journal* of this Society for November, 1911, page 1437.

MECHANICAL STOKERS

For burning low-grade coals running high in ash and volatile matter, the chain-grate stoker is unexcelled. This is principally because the ash is continuously and automatically removed from the furnace without hand labor and without disturbing the fire. Also, the simplicity of the device and its slow movement tend to keep repair costs at an exceedingly low point. There is, however, one inherent defect in the chain-grate principle, which renders it difficult for this type of stoker to compete with inclined-grate stokers and underfeed forced-draft stokers in these localities where high grades of fuel are used, and that is that the fuel bed on a chain grate must be thick in front and thin at the back end. This, of course, means that cold air in large quantities is continuously entering the furnace, impeded only by the ash on the back end of the grate. As a result the flue gas from a chain-grate furnace seldom averages more than 8 or 10 per cent CO_2, whereas, with other types of stoker, it will run from 12 to 15 per cent, indicating a correspondingly higher efficiency.

As the back end of a chain grate is quite bare of fuel and is exposed to the heat of the furnace, it would be injured by the heat were it not for its covering of ash and for the air which passes through it. Therefore, if such a grate were fed with a coal low in ash and which would tend to cake or run on the grate and choke up the air spaces, we might expect the grate to get hot and suffer injury. This, in fact, is what often occurs with some grades of coal, and several chain-grate installations

have been discarded on this account. Recently, however, improvements have been made in the chain grate which better the performance in the above-mentioned respects. An air or water-cooled back is installed against the bridge wall in such a way that fuel is banked up at this point, thereby cutting down the excess air; and a short auxiliary inclined grate is used in one type of stoker upon which the coal is first coked before reaching the main chain grate.

While it is possible with hand-firing to run a properly constructed furnace at about normal rating without an objectionable amount of smoke, it is practically impossible to have all of the furnaces in a large boiler-room so fired all the time. With mechanical stoking, however, it is possible to so construct the furnaces that they will be practically smoke-proof after the brick-work becomes heated. The maintenance of the mechanical parts of the chain-grate stokers is not considerable, but for the walls and arches of the furnace the repairs become a serious matter in those furnaces which are tile-roofed. With the other types of stoker for higher-grade coals, the repairs to the stoker ironwork will be considerably greater, while the repairs to the furnace brick-work will be proportionately less. Excessive furnace repairs, therefore, are one of the penalties paid for high temperature, capacity and efficiency, and smokelessness.

Stokers of such types as the Taylor, Roney, Jones and Murphy are more adaptable for higher-grade eastern coals, in which the ash is 12 per cent or less, and they are used more generally in the east and north than is the chain-grate type. Stokers such as the under-feed type, with which forced draft is used, probably have some advantages over the other types of stoker, from the point of view of meeting an emergency very quickly, and also, in cases where stacks for natural draft are not high enough, of developing high boiler ratings. In respect to efficiency of combustion, other conditions being the same, this does not vary greatly with the different types of stoker, considering that the proper type is used for a given grade of coal.

STEAM-FLOW METERS

All methods of determining the weight of steam flowing in a pipe in a unit of time are based upon the velocity of the flow, and to determine the velocity two principal methods are employed:

One, an obstruction placed in the pipe, the drop in pressure around this obstruction being a function of the flow velocity; the other method is to place in the steam-pipe a tube against whose open end the flowing steam impinges, thus creating in the tube a static pressure relatively greater than the pressure in the steam-pipe, and which difference in pressure is a measure of the steam-flow velocity.

Such methods are accurate only with steam of constant pressure and quality. Automatic corrections for variation in quality are impossible, but corrections for pressure variations are made at the expense of some considerable complication in the apparatus.

However, as variations in pressure in excess of 5 per cent seldom last for any considerable length of time, and as such variations above and below normal tend to offset each other in the record, and as a difference of 5 per cent in high-pressure steam represents a difference of only about 2 per cent in the amount of heat carried in the steam, it is apparent that the indications of such instruments uncorrected for pressure are sufficiently accurate for all but the most exact determinations.

Tests made on General Electric flow-meters of this type by Prof. Gebhardt, of the Armour Institute, showed an inaccuracy of from 1 to 8 per cent. These tests presumably covered a wide range of pressure. Tests made by the Union Electric Light and Power Company, of St. Louis, under working conditions showed an agreement within 2 per cent of measurements obtained with tank and weighing scales. These results were practically confirmed in tests by the Commonwealth Edison Company, of Chicago, and by the Boston Edison Company.

With such a degree of accuracy, the value of such an instrument as an adjunct to a steam-gauge on a boiler is manifest, as it promptly indicates any variation in boiler output caused by such usual operations as opening and closing of dampers, fire-doors, feed-water valves, etc., and the effect of thick, thin or uneven, clean or dirty fires.

In any large boiler-room there is always a wide difference between results obtained under test conditions with a single boiler and under operating conditions with all boilers. This is because of the impossibility of telling which boilers are not up to condition and which firemen are careless or shirking; but if

each boiler were equipped with a steam-flow indicator, it would be possible for the boiler-room foreman to say at once whether or not any particular boiler is doing its proper share of the work, and with a steam-flow meter constantly staring him in the face and instantly pointing out every error made, a fireman cannot help improving the quality of his work. (See Figure 5.)

As previously indicated, a simple-flow meter without means for correcting for pressure variation is sufficiently accurate for the determination of boiler-room operating results, but to carefully check up the performance of a large turbine and detect any

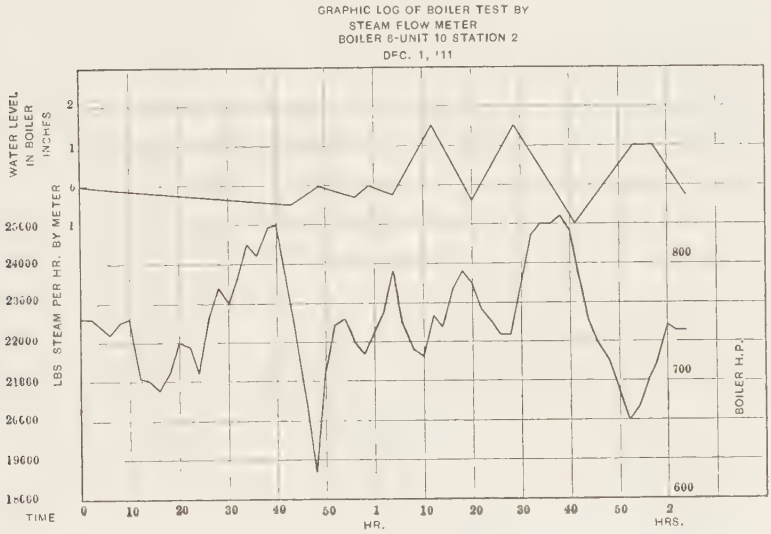


Fig. 5

falling off in its efficiency the most accurate instruments available should be employed. For this purpose it is advisable to use the more elaborate devices equipped with means for compensating for fluctuations in pressure. Turbine manufacturers, as well as central-station operators, consider it advisable to equip all large units, say from 5000 kw up, with flow meters. A slight derangement of the nozzles or blades of a turbine would not be accompanied by any noticeable impairment of the smoothness with which the machine operates, and yet a flow meter would reveal an increasing rate of steam consumption, warranting the immediate overhauling of the unit to prevent the needless waste of fuel.

FEED-WATER REGULATORS

The advent of the flow meter brings to light the fact that the greatest variations in the amount of work which a boiler does are caused by varying the supply of feed water, and to eliminate the fluctuations due to this cause, so that the flow-meter indications will refer solely to the manipulation of the fire, the feed-water regulator at once suggests itself. An inquiry, however, into the various makes of regulators now on the market shows that their action is intermittent, and the boiler is either taking water in considerable quantities or the feed valve is entirely closed, the result being rapid changes through a wide range in the rate of steaming as shown by the flow meter.

This condition suggests the desirability of a feed-water system supplied by a centrifugal pump and regulated at each boiler by an automatically controlled valve capable of differential variation according to height of water and rate of steaming.

PITTING OF FEED-WATER PIPING

Wrought-iron or steel pipe in feed-water lines is frequently a source of much expense and annoyance. For reasons which cannot be readily determined, it sometimes appears that this deterioration is due to the presence in the feed water of some organic substance which is broken up by heat and forms an acid which attacks the inside of the pipe, or which by its presence stimulates corrosive action of some other kind. It has been found in one instance that such corrosive action varies with the amount of air in the feed water. In such cases the deterioration of the feed pipe can be nearly all overcome by preventing the aeration of the feed water. This can be accomplished by admitting the make-up water into the system through the condenser. The air is then removed by the air pump, and if a closed system is used between the condenser and the boiler-feed pump the water cannot re-absorb air.

In another case it was found the injury to the feed-water line was caused by an acid which is produced by the breaking down of the animal-oil constituent of the cylinder oil.

When it is not possible to remove the cause of pitting, it is possible to prevent it by the adoption of a metal which will resist the corrosive action, such as brass or cast-iron, or by using a thin copper tube as a lining for steel pipe.

FATIGUE OF CAST-IRON USED IN CONNECTION WITH SUPERHEATED STEAM

It is now the general practise to avoid the use of cast-iron fittings in piping carrying superheated steam, although many such installations are still in use and with no indications of distress in the metal due to the high temperature of the steam.

A case of failure of a cast-iron fitting which formed part of a superheater occurred in the power house of the Union Electric Light and Power Company, of St. Louis. The temperature of the steam in this case was 455 degrees, and the temperature of the surrounding gas ran as high as 600 degrees. The failure was in the nature of a small crack in a cast-iron outlet, and as there were nearly 5000 similar castings in service under the same conditions, apprehension existed that cast-iron was not a safe metal to use for the purpose. On this account the defective piece was removed and cut up and sample pieces were subjected to careful physical tests. The examination was made in the testing laboratory of the Columbia University, and the conclusion reached was that:

> "The tensile strength of the cast-iron outside the small zone where the crack occurred is quite as high as that of good grades of grey iron, and the condition of service does not seem to have caused a material loss of strength of the metal.
>
> The crack which occurred was due to the segregation of foreign matter in the casting, the area thus affected being small, but in exactly the proper position to receive the stresses which might be induced by the expansion of a pipe in the opening."

Against the earlier experience of the St. Louis Company we may instance the later experience of that company and of various other large companies who were compelled to replace a great quantity of cast-iron fittings in superheated steam lines because of distortions and failures. A test made on pieces cut from the body of a cast-iron valve taken from a superheated steam line of the Commonwealth Edison Company was reported in *The Valve World* for March, 1908, and is in part as follows:

> "Crane Company has been very anxious to obtain something definite on this important subject, and the opportunity for investigation presented itself a few months ago when a 14-in. high-pressure gate valve, which had been in service for four years, was taken out and replaced by a

steel valve of similar design. The company, having a complete record of the tests of the iron which was used at the time this valve was made, was in a position to determine accurately what the effect of a long-continued superheated steam really was. The salient points are:

A loss of strength in the body of 49 per cent, while the metal in the flanges not being under quite so high a heat and not directly exposed to the action of the steam, showed a loss of only 33 1-3 per cent.

Following is the detailed result:

Test on 14-in. No. 9-E cast-iron gate valve, extra heavy, removed from a superheated steam line.

Steam on line, about August, 1903.

Valve taken out, September, 1907.

Time in service, four years.

Pressure of steam, 200 lb. per sq. in.

Temperature of steam, about 590 degrees, sometimes a little higher.

Original strength of cast-iron, as shown by test-bars, 22,400 lb. t.s.

Strength of bars cut from body of valve, 12,303 lb. t.s., 11,608 lb. t.s., 10,610 lb. t.s., 12,440 lb. t.s.; average strength, 11,740 lb. t.s.

Loss of strength in body after four years' service as compared with original test-bars, 49 per cent.

Strength of bars cut from the flanges on the valve, 14,900 lb. t.s., 15,250 lb. t.s.; average, 15,075 lb. t.s.

Loss of strength, 33 1-3 per cent."

The valve above referred to was 22½ in. long when it was installed in the line, and was 22 13-16 in. long when it was taken out, showing an elongation of 5-16 in.

The following extract is from a publication issued by the Crane Company and entitled "The Effect of Superheated Steam on Valves and Fittings:"

"Cast-iron subjected to superheated steam having a temperature exceeding 500 degrees F.—and we say 500 degrees simply because we know the effect is produced beyond that point and we do not know whether a lower temperature is equally bad—undergoes a slow, constant increase in volume with a consequent loss of strength.

As steel does not appear to increase permanently in volume at temperatures of 500 to 800 degrees F., we may assume that cast-iron is so affected on account of the larger volume of elements, such as carbon and silicon, contained in that metal. It may be noted in this connection that cast-iron is made up of approximately 92½ per

> cent iron and 7½ per cent of other elements by weight, but the iron is so much heavier than the carbon, silicon, sulphur or phosphorus that when we consider a cube of cast-iron by volume we find the elements other than iron, instead of occupying 7½ per cent of the cube, take up about one-third, hence there is a very large portion of cast-iron which may be affected. Cast-steel, on the other hand, contains only about .6 of 1 per cent of carbon, silicon, sulphur and phosphorous, an amount altogether too small to have an effect upon the total volume."

Undoubtedly the deterioration of cast-iron in superheated steam lines is due to frequent and rapid changes in temperature within the range of the superheat. For example, suppose a steam line carrying steam having a normal superheat of 150 degrees. If, when running at full load, the greater part of the load were suddenly thrown off, the superheat temperature might rise to 200 or 225 degrees. If now the entire load were thrown off, the temperature of the steam and of steam piping would fall 200 degrees or more to the temperature incident to the steam pressure.

Suppose, again, while running under normal conditions and with 150 degrees of superheat, water should be carried over from one of the boilers through the superheater and into the steam line. This water would have a temperature 150 degrees less than that of the steam pipe, and the effect on any cast-iron fitting with which it came in contact would be exactly the same as would be produced by pouring water on a hot stove-plate. The metal would warp and its inner surface would shrink and be permeated with cracks, microscopical in size at first, but which would be extended from time to time until the strength of the entire casting was seriously impaired.

For further investigation of this subject reference may be had to *The American Society of Mechanical Engineers' Transactions for the year* 1910, Vol. XXXI, page 989.

The conclusion is that cast-iron fittings in a superheated steam line constitute a hazard, and that the danger increases with the amount of the superheat, and on this account your Committee strongly advises against the use of this metal for such purposes.

SURFACE-COMBUSTION BOILERS

A new method of burning gaseous fuel has recently been developed by Prof. Bone, of Leeds, England. This method,

which is called "surface combustion," utilizes, first, the principle that a gas burns more readily when in contact with an incandescent surface than it does as a free flame, and under favorable conditions will burn in contact with such surfaces *without any flame at all;* and, second, the principle that the absorption of heat by the metal of a boiler plate or tube is many times more rapid when the heat is radiated from an incandescent solid than when the metal receives its heat from contact with a hot gas.

This principle has been applied to many forms of industrial appliances with considerable success, and, in addition, has been commercially adapted to fire-tube boilers.

To make a success of such combustion, this type of boiler is constructed differently from the general practise in this country. The tubes are very short, not exceeding 3 or 4 ft., and are loosely filled with broken fire-brick or non-fusing material.

The gas is mixed with the correct amount of air for perfect combustion, and forced into this material in the tubes, where combustion takes place with great rapidity. The amount of water evaporated per square foot of heating surface is enormous, averaging 20 lb.

The efficiencies obtained on tests are quoted as approximating 94½ per cent, but these figures are computed on a different basis from that generally used in this country.

In the first place, the net heating value of the gas is taken as the basis, and, in addition, the heat absorbed by the feed-water heater is included, and the power necessary for the induced draft is not taken into account. To make a comparison with the efficiencies obtained in American practise it is necessary to include these aditional items, which will reduce the quoted efficiency of 94½ per cent to 80 or 82 per cent.

HIGH-EFFICIENCY SELF-CONTAINED STEAM UNITS

Several makes of high-efficiency reciprocating steam engines, such as Stumpf, Wolf, Lenz, Locomobile and Memming types, are now being exploited abroad. In general these units, which are equipped with condensers and are usually mounted on their boilers, use steam at 200 lb. or more pressure and with 200 degrees of superheat, and have their cylinders jacketed in some instances with live steam and in others with hot gases from the

smoke extension of the boiler. More detailed information concerning these engines may be found in recent technical literature.

The efficiency attained by these units when running condensing is remarkable, considering their small size. A consumption of steam as low as 16.5 lb. per kw-hour has been reported on a test of a Stumpf engine, and equally good efficiencies are reported for other makes of engines of this general class.

While the unit is compact and economical and unquestionably has a field of usefulness in countries where labor is cheap and fuel is dear, yet there are other features about this type of engine which account for its lack of recognition in this country, among which might be mentioned high grade of attendance required, difficulties of cylinder lubrication, and excessive cylinder wear when using steam at a temperature around 600 degrees F. Also objections are raised on account of the presence of coal and ashes in the engine-room, and because the entire unit must be out of service while repairs are being made on either engine or boiler.

DEVELOPMENTS IN THE STEAM TURBINE DURING THE PAST YEAR

The Southwark Foundry and Machine Company, of Philadelphia, has secured rights to manufacture turbines of the Rateau type in the United States. This company has advised your Committee that they now have several turbo-generators under construction or in operation, varying in size from 600 to 3000 kw.

The merits of this type of turbine which the manufacturers point out in their letter to your Committee are: Low steam velocities through the turbine, ample clearance with good steam economy, simplicity of design, no unbalanced pressure on the rotating element and no accompanying auxiliaries.

As the general features of the Rateau turbine were very completely described in the paper presented to this Association at Atlantic City in 1909 by Mr. C. H. Smoot, no detailed description seems necessary at this time.

Turbines Built by the Westinghouse Machine Company

The above company advises your Committee as follows:

> "There have been no radical developments since our last report. We have been adding very materially to our sizes and to variations in types for special conditions, and

our work of the last year has been chiefly devoted to extending the application of the turbine. It seems to us that your Committee might think well of bringing out this point of the wider application of the turbine to various purposes. It seems only a short time ago that the turbine was available only for alternating-current work, and was essentially a condensing machine. Now, we have turbines that give fairly good economy running non-condensing. We have machines (the Bleeder type) which may be run condensing or non-condensing at will, furnishing steam for other purposes—in fact, giving their normal condensing efficiency while bleeding off steam in any desired quantity. Then we have standard condensing turbines applicable to large direct-current service by means of the reduction gear, quite a number of such plants being now in successful operation. Then, of course, we have low-pressure and mixed-pressure turbines, whose application to existing reciprocating engine plants oftentimes show very large reductions in the cost of operation. We have turbines for driving blowers for pressures anywhere from 1 or 2 oz. up to 30 or 40 lb., such blowers having been developed with efficiencies of from 70 to 75 per cent, and the smaller sizes of turbines have been successfully applied to auxiliary work, such as pump drive, operating fans, etc.

Our report this year shows our activity to have been more along the line of the extended application of turbines to different classes of service than to the bringing out of any marked changes in design. You might speak of the success we have had with large high-speed turbines. The city electric machine at San Francisco, having a maximum capacity of 15,000-kw at 1800 r.p.m., has run without any trouble whatever for a year past. We recently took an order for a 20,000 kw machine at 1500 r.p.m. There is much to be said in favor of such machines, which have demonstrated successful mechanical operation, for their economy is very high, the stresses are kept within good limits, and the smaller parts incident to their high speeds are, because of their smallness, certain to be of structural integrity."

Turbines Built by the General Electric Company

The above company advises your Committee as follows:

"During the past year we have made all the improvements and changes suggested in last year's report, and we wish to call your attention particularly to the fact that all large machines are now designed with removable nozzles for all stages. You will also be interested in

knowing that many large Curtis turbines which will be built during the present year will have added to the low-pressure end of the turbine a wheel carrying a single row of buckets for the purpose of relieving congestion and thereby improving the efficiency.

The General Electric Company is prepared to furnish Curtis turbines of the horizontal shaft type of any capacity desired."

CONDENSER PERFORMANCE AND ECONOMICAL VACUUM

Radical changes have been made during the past two years in condenser design, the effort being to so arrange the tubes and baffle the flow of steam that the steam side of the tubes will be readily freed of condensation and that the entrained air will be swept toward the dry vacuum pump suction and over a nest of special tubes designed to condense any remaining steam in the air, thus reducing the volume of the vapor handled by the pump; but probably the greatest improvement has come about through a realization that additional cooling surface in a condenser is of little value unless ample provision is made for the steam to reach it without undue loss of pressure.

An inspection of a curve showing how the theoretical thermal efficiency of a perfect steam engine varies with terminal pressures indicates that the most promising field of endeavor for increased efficiency in steam-turbine work lies in the production and maintenance of the highest vacuums obtainable, as shown by Fig. 6, in which the reduction of terminal pressure from .4 lb. to .2 lb. indicates an addition of about 8 per cent in the theoretical amount of energy available, and this saving is double the amount which would be saved by a reduction in pressure from .6 lb. to .4 lb.

It has often been demonstrated that vacuums may be improved by removing many of the tubes to provide liberal passages for the steam to distribute among the remaining tubes without excessive velocities or loss of pressure.

Another advantage to be obtained by the opening of steam passages and a reduction of steam velocities is the elimination of whirling and creeping of tubes, which result in their becoming loose in the packing and even in being worn through in the tube plate.

The importance of this is apparent when we consider that a 12,000-kw turbine, when running at full load and with a condenser pressure of 1½-lb. absolute pressure, is discharging into the condenser each second 600 cu. ft. of steam; and if in the first pass of the condenser there is between all of the tubes of the first row only 10 sq. ft. of passage, the steam must have a velocity of 600 ft. per second, which can only be attained at the

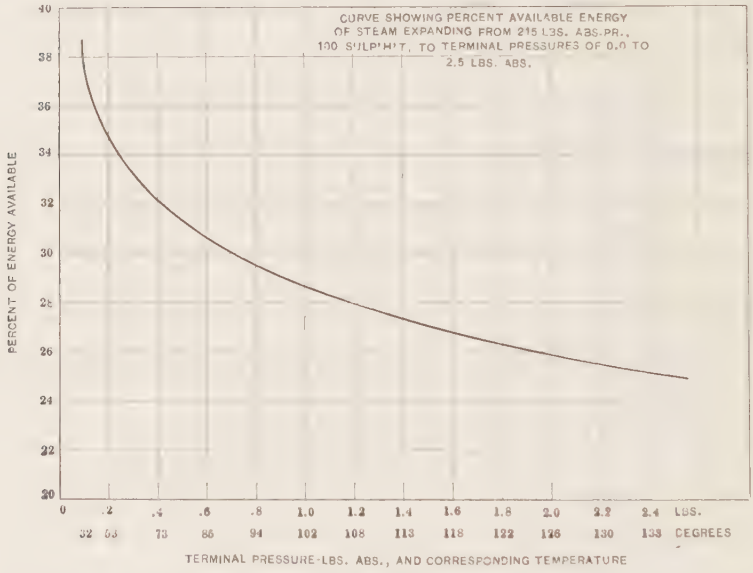


Fig. 6

expense of a considerable amount of back pressure on the turbine, with a corresponding loss of efficiency.

Where condensing water is plentiful, but so dirty that the amount flowing through the condenser is restricted, due to the tubes being choked, relief may be obtained by the installation of grid-iron valves so located that the path of the circulating water may be readily changed from 3-pass to single-pass, thus reducing the friction to the flow and increasing the amount of cooling water.

LIFE OF CONDENSER TUBES

There has been very little development during the past year on this subject. One large company reports that it is experimenting with tubes of different compositions, the two

principal types being Admiralty (70 per cent copper, 29 per cent zinc and 1 per cent tin) and Benedict bronze (92 per cent copper and 8 per cent aluminum). Sufficient time, however, has not elapsed to warrant the drawing of any conclusions.

Another company that has had very serious tube troubles reports an installation of Benedict bronze tubes in a 32,000-ft. condenser for nearly three years with no indication of deterioration of any kind, while a similar installation a few months old is quite disappointing.

The so-called Cumberland protective process is being tried out in several stations. The method employed consists of passing a small current of from 10 to 20 amperes through the tubes of the condenser to the ground in such a way that the tubes are made electro-negative to the water surrounding them. This system has not been in service a sufficient time to warrant any statements in regard to its value.

MOISTURE IN THE EXHAUST STEAM OF ENGINES AND TURBINES

For many reasons it is highly desirable to ascertain the quality of the exhaust steam of engines and turbines, but, owing to the fact that the moisture is not evenly distributed throughout the cross-section of the exhaust discharge, this is usually a very difficult problem.

One company reports, as below, its experience in investigating this subject:

> To make a practical determination of the percentage of moisture present in the exhaust of the 46 × 94 low-pressure cylinder of a vertical cross-compound engine, operating on 25 in. of vacuum, with steam at 175-lb. pressure and with 45 degrees of superheat, openings were made into the exhaust chamber and a nozzle inserted, which was piped through a Carpenter separating calorimeter and a small condenser and connected to the dry vacuum pump which served the engine.
>
> The relative amounts of water collected in a given time by the calorimeter and by the condenser were, of course, an indication of the percentage of moisture carried by the exhaust steam. This same apparatus was later connected to the exhaust chamber of a steam turbine operating on 27½ in. vacuum. The averages obtained in each of these two tests indicated that the exhaust of the reciprocating engine carried 14 per cent of moisture and

the exhaust of the turbine carried 16 per cent of moisture, although determinations made at different parts of the exhaust pipe of the engine gave results varying from 6 to 28 per cent, and the determinations made in different parts of the turbine base gave results varying from 6 to 18 per cent.

Probably the most carefully conducted investigation of this subject is that reported by Messrs. Stott and Pigott in a paper read before The American Society of Mechanical Engineers in December, 1910, and published in the *Transactions for* 1911, Vol. XXXII, page 69.

It is reported that the Government Bureau of Standards is about to make an investigation of this general subject.

IMPROVEMENTS IN REDUCTION GEAR

An improvement in speed-reduction gear from very high to moderately low speeds, which has been brought out by the Westinghouse Machine Company, and used for driving direct-current generators, pumps and shafting with steam turbines, has, from a recent general inspection of those units in service, been found to be very successful. The gearing does not show any perceptible wear and it is practically noiseless.

The essential and distinctively novel feature of this design is the hydraulically supported frame which carries the pinion shaft and its bearings, and by virtue of which the pinion shaft is self-aligning, responding instantly to the smallest unbalancing of the tooth pressure. This method of suspending the pinion-bearing frame not only insures the most perfect balancing of tooth pressures, but the fluid cushion interposed between the pinion shaft and the main casing of the gear silences in a large measure the noise usually associated with the operation of high-speed toothed gearing and prevents all shock or jar from the rapid contacting of the teeth.

With this gear-reduction device speed reductions are made from 3600 to 720 r.p.m.

A 500-kw direct-current unit of these speeds has been in service for over a year at the Commonwealth Steel Company, East St. Louis, with excellent results. Such units are made in capacities up to 2000 hp. Two sets are in use by the navy driving propeller shafts on Collier "Neptune," with which the speed reduction is from 1250 to 130 r.p.m., transmitting approximately 4000 hp each.

A full description of this gear may be found in *The Electrical Journal* of January, 1912.

GAS POWER

Owing to the increasing ramifications of gas-power engineering, the subject becomes of very comprehensive character. Several of the preceding Committees have presented to the Association those developments which have shown themselves to be of first importance. As many new phases are constantly arising, and it is believed that many of the facts relating thereto are deserving of the observation of the Association, a broad survey has accordingly been made of the subject, treating generally of prime movers of the internal-combustion type, including oil and gas-engine apparatus and modifications thereof.

In considering oil as a source of fuel supply, there are certain factors in oil production and distribution and in its qualities which will exert an influence upon the use and growth of the oil engine for stationary-power purposes, and therefore general statements bearing thereon have been presented under this section of the report.

OIL AVAILABLE FOR POWER PURPOSES

The following statistics of petroleum production and amount of oil available for power purposes are taken from the *Mineral Resources of the United States in* 1909, in barrels of 42 gallons:

	East of Rocky Mountains	Per Cent	West of Rocky Mountains	Per Cent	Total	Per Cent
Total Production (crude)	127,224,000	100.0	54,776,000	100.0	182,000,000	100.0
Exports (crude)	1,100,000	.8	4,084,700	7.4	5,184,700	2.8
Domestic consumption	126,124,000	99.2	50,691,300	92.6	176,815,300	97.2
Total amt. available as gas and fuel oil	35,315,000	100.0	32,949,000	100.0	68,264,000	100.0
Exports (gas and oil)	900,000	2.5	2,001,000	6.1	2,901,000	4.2
Domestic consumption (gas and fuel oil)	34,415,000	97.5	30,948,000	93.9	65,363,000	95.8
Oil burned in locomotives	10,000,000	28.3	10,000,000	30.3	20,000,000	29.3
Used in gas making	11,254,000	31.9	1,930,000	5.9	13,184,000	19.3
Available for power, etc.	13,161,000	37.3	19,018,000	57.7	32,179,000	47.2

The amount of fuel oil available from crude oil is obtained by using the factor .28 for the eastern oil and the factor .65 for the western oil. These factors represent the amount of fuel oil obtained from crude petroleum in actual practise. The amount of oil burned in locomotives is divided equally among the eastern and western States, by inspection of the list of railroads using oil as fuel.

Oil production and consumption has been divided into two parts—that in the territory east of the Rocky Mountains, and that in the territory west of the Rocky Mountains. The territory west of the Rocky Mountains is taken as including the States of Montana, Wyoming, California, New Mexico, Colorado, Washington, Oregon, Utah, Nevada and Arizona.

Those east of the Rocky Mountains include all others.

These estimates of fuel oil available for power purposes are, of course, only approximate, but will indicate in a general way the geographical location of the production, and likewise some general idea of the quantity available for power purposes.

The total production of crude petroleum in 1910 (United States Geological Survey) was 209,500,000 barrels, of which 73,000,000 barrels were produced west of the Rocky Mountains, and 136,500,000 barrels were produced east of the Rocky Mountains.

No statistics of a later date were available, but the *Engineering and Mining Journal,* issue of January 6, 1912, estimates that the production of crude petroleum, in the year 1911, was 210,000,000 barrels, of which 77,800,000 barrels were produced west of the Rocky Mountains, and 132,200,000 barrels were produced east of the Rocky Mountains.

It will be seen that the production of the entire United States shows a slight increase, in spite of the fact that the oil fields east of the Rocky Mountains show a decrease. The production in California, in the year 1911, was 10,500,000 barrels in excess of the consumption, and this over-production had a natural tendency to stop any further drilling. In the east the number of oil wells drilled showed a decrease over previous years. In the Appalachian and Lima fields no new pools were discovered, but in the Texas and mid-Continental fields several new pools were discovered.

Again, in viewing oil as a source of power, it is well to bear in mind its relation to the production of coal.

OIL SPECIFICATIONS FOR ENGINE FUEL

Fuel oil as supplied for power purposes consists ordinarily of a distillate that comes from the distillation of crude petroleum after the gasoline, kerosene and lubricating oils have been abstracted. It distills at temperatures from 300 to 700 degrees F., and varies in gravity from 40 to probably 20 degrees Beaume. It has been the experience of purchasers to find that the fuel oil supplied consists of such oils as cannot be disposed of at a higher price for other purposes, leaving a residue available for power purposes or as a gas-making material. There are, however, certain requirements for both of these purposes that limit the oil supplied to those that do not contain any large percentage of moisture, acid or sulphur.

The modern oil engine has been able to handle fuel oils successfully that are as heavy as 17 degrees Beaume, and as light as kerosene, or 40 to 48 degrees Beaume. Of course such engines as gasoline engines handle the lighter oils with great ease, but the great difficulty has been to develop an engine that would use these heavy oils that are not so easily vaporized. The latter has at last been accomplished satisfactorily by building engines whose final compression temperatures have been high enough to produce a heat that would completely burn the oil.

The oil which different types of engines may burn satisfactorily varies in a large degree with the inherent feature of the design.

One of the standard manufacturers quotes specifications as follows:

"Gravity not to exceed 19 degrees Beaume.

"Oil to be free from acid, asphaltum and non-combustible solids.

"Oil to contain not more than .3 of 1 per cent of either sulphur or water.

"Heat value to be not less than 18,000 B.t.u. per pound."

A second manufacturer quotes for one type of engine that the oil shall have a gravity exceeding 18 degrees Beaume; shall have a flash-point from 100 to 250 degrees F., and a heating value of 18,000 B.t.u. per pound; to be free from acid, and to contain not more than 1/3 of 1 per cent of sulphur or of water.

The makers of this engine state that it makes no difference

whether the oils have an asphaltum or paraffine base when used with one of their type of engines.

A type of engine which is operated with a compression lower than that necessary to vaporize the oil uses a pre-heater to assist in the vaporization of the oil previous to its admission into the cylinder. This type of engine demands that the pre-heater shall be heated from an external source on starting.

The heating values of oils are found to vary from about 18,000 to 20,000 B.t.u. per pound, and these heating values seem to bear an almost direct relation to their density. The oils in use seem to average approximately 19,500 B.t.u. per pound.

The use of fuel oils of an asphaltum base have not been as general as the use of those having a paraffine base, as the asphaltum-base oils have been found at times to cause a deposition of carbon in the cylinders, necessitating more frequent cleaning.

In Germany, and also in some cases in the United States, gas-house tar has been successfully used as a fuel in engines of the Diesel type, but its use has not been proven entirely satisfactory, as it is practically impossible to completely free it of water, and a small quantity of water in any fuel oil will cause the engine to miss fire and give poor speed-regulation, so it has been found more economical to substitute a better grade of fuel oil.

As fuel oil to-day is generally purchased on a gravity basis, expressed in degrees Beaume, it is thought advisable to attach the following table to show the relation of the gravity so expressed in terms of the actual specific gravity.

COMPARISON TABLE OF SPECIFIC GRAVITY OF LIQUIDS LIGHTER THAN WATER

Beaume, Degrees	Specific Gravity Water = 1.00
15	.966
20	.933
25	.903
30	.875
35	.849
40	.824
45	.800
50	.778
55	.757
60	.737

More complete tables will be found in standard handbooks.

The character of the fuel oil is not always dependent upon the nature and quality of the original crude oil, as the methods of distillation are such that a uniform grade of residual oil is not always produced. The percentages of the lighter oils derived from any crude oil vary greatly, and these percentages change the character of the residual oil available for fuel purposes. However, the various grades of fuel oil, as now supplied for power purposes, give satisfactory results, if free from objectionable ingredients, such as sulphur, moisture and acids, the acid being an ingredient that is mixed with the oil during its purification after distillation.

Sulphur, which may appear in various fuels when gasified, takes the form of SO_3 or CS_2 and more commonly SO_3. In a dry gas these compounds produce no harmful results upon the working parts of the engine, but in the presence of vapor or moisture their effect may become very marked and, in fact, quite troublesome. This is mostly true of SO_3, which combines with water, creating vicious sulphuric acid, and attacks the parts exposed to its action in a degree depending upon its strength. The presence of excessive sulphur in fuel manifests itself in the nature of excessive deterioration of pistons, piston rings, cylinder walls and the exhaust valves and stems. Leaky pistons may allow the acid gas to reach the crank case, and in a splash system, where water may be present, the bearings and polished surfaces will soon give evidence of its presence. Causes of excessive wear which may at first be mysterious are often traced to the sulphur ingredient. Fuel oil should not contain more than 1/2 per cent when no water is carried by the oil, and not exceed 1/3 per cent with 1/3 per cent of moisture existing. Refineries, for these reasons, furnish what is termed "de-sulphurized" fuel oil when specifications are made accordingly.

As oil is purchased on a volumetric basis, it is in many instances desirable to correct the volume, for changes in temperature should be taken into account.

In handling oil in car-load lots, it is advisable to always syphon or pump the oil from the opening in top of car and not unload by gravity from the connection at the bottom, some serious accidents having occurred through inability to control the flow when the valves in the car were in faulty condition.

OIL ENGINES

The oil engine differs from the more familiar gas engine only in that the fuel must be prepared for combustion at the engine, or injected at high pressures, and therefore either a carburetor, vaporizer or an injection valve must be provided for vaporizing or atomizing the liquid-oil fuel, depending upon whether low, high or modified compression types of engines are used. The simple automobile engine comes within the former class (low pressure). For power purposes the low-pressure engine usually employs a hot-bulb or "preheating chamber," which enables the engine to burn comparatively low-grade oils. The Diesel engine, which has gained much prominence in the past few years, employs high-combustion pressures (500 lb., approximately) and requires an air-injection pressure of about 1000 lb. In most low-pressure oil engines the 4-cycle principle, known as the Beau de Rochas cycle, as usually adopted in the gas engine, is the general practise. On the other hand, the Diesel motor has a cycle peculiar to itself, and the distinguishing feature is that the fuel is injected at constant pressure for about 10 per cent of the working stroke, while the air is hot enough by reason of the high compression to cause combustion on contact. Oil engines built to operate on the two-cycle principle may be specially desirable where weight and space must be critically considered, but they suffer somewhat in economy and simplicity of design. On account of the use of pure air for scavenging there is a gain from over-scavenging.

With the fuel admitted only after the working stroke begins, there is no opportunity for a premature explosion to take place. Moreover, as only a small clearance of about 7 per cent is necessary, more complete scavenging may be effected, which improves the efficiency accordingly.

The long-sustained high pressure and temperature of the regular Diesel engine obviously places some severity upon the operating parts, thereby requiring sturdy construction. On the other hand, the suddenly applied pressure in the low-pressure type, Beau de Rochas or Otto cycle, introduces high stresses which must also be provided for.

In point of fuel economy the superiority of the Diesel type has been very well established. Regarding maintenance and attendance, the low-pressure type has much in its favor. This

would lead to the opinion that for the larger sizes, exceeding 150 hp, the Diesel motor should be chosen, while in case of small power requirements (under 100 hp) the low-pressure type would generally be used. In the neighborhood of 100 to 150 hp the field will be disputed between the two according to existing fuel prices and local conditions. There has been developed a design which may be termed a "compromise" between the low-pressure hot-bulb and the Diesel high-compression engines, for which there is claimed a fuel economy comparative with the Diesel motors, although it employs lower working pressures.

There are many designs of carburetors and vaporizer needle-valves which may be attached to the oil engine, and these are extensively treated in many engineering articles and publications.

Those manufacturers who have been most actively engaged in building engines using the heavier grades of oil are as follows:

The American Diesel Engine Company, or Busch, Sulzer Brothers Diesel Engine Company, St. Louis, Mo.
The De La Vergne Machine Company, New York, N. Y.
The Atlas Engine Works, Indianapolis, Ind.

There are a number of companies, however, who are building engines for stationary power, but these are principally engines that use the lighter grades of oil.

Among these companies are:

August Mietz Iron Foundry and Machine Company, New York, N. Y.
Covington Machine Company, Covington, Va.
Elyria Gas Power Company, Elyria, Ohio.
Fairbanks-Morse Mfg. Company, Beloit, Wisc.
General Electric Company, Schenectady, N. Y.
Remington Oil Engine Company, Stamford, Conn.
St. Marys Machine Company, St. Marys, Ohio.
The Westinghouse Machine Company, East Pittsburgh, Pa.

It is authoritatively reported that the following builders have either been studying the problem or else are directly experimenting and planning to place their own designs of oil engines on the market:

Providence Engineering Works, Providence, R. I.
Southwark Foundry and Machine Company, Philadelphia, Pa.
The Westinghouse Machine Company, East Pittsburgh, Pa.

The guarantees on oil engines ordinarily offered by the manufacturers in the past, are as follows for loads between three-fourths and full-load rating:

Diesel

Oil consumption not to exceed .5 lb. per brake hp-hr.

De La Vergne

Oil consumption not to exceed .6 lb. per brake hp-hr.

Hornsby-Akroyd

Oil consumption not to exceed 1.00 lb. per brake hp-hr.

Oil not to contain less than 18,500 B.t.u. per pound.

The main distinction between the last two, is the employment of higher compression pressures.

RESULTS FROM OIL-ENGINE PLANTS

Oil engines have been used in this country in a limited way since about 1903, but the increase in installations has been quite marked within the last two or three years. The following number of installations and individual electric generating units have been reported to the Committee:

	No. of Installations	No. of Units
Diesel	59	146
De La Vergne	23	59
	82	205

These represent what may be classified as large oil engines, above 50 to 75 hp, as distinguished from the numerous smaller units which in the main operate on gasoline or other good grades of oil. Several other responsible builders having installed engines which might have been included in the above table had information been received in time, your Committee wishes to avoid giving the impression that this is a complete listing. However, it is quite indicative of the progress made with engines consuming the heavier oils.

Your Committee has sent inquiries to a majority of the plants brought to its attention where it was thought useful information regarding their operation might be obtained. The response has been in a large measure very gratifying, and a tabulation of the principal points of interest has thereby been made from the replies which contained direct statements of their working results (Fig. No. 7). Many owners have expressed themselves very fully in regard to the characteristics and general performance of these engines, and your Committee has decided that it will be of interest to the membership to summarize these

PLANT NUMBER	CHARACTER OF LOAD	DATE UNITS PUT IN OPERATION	NUMBER OF UNITS	INDIVIDUAL B.H.P.	TYPE	VERT. OR HOR.	NO. OF CYLS.	DIAMETER & CRUMB OF STROKE	RATED SPEED R.P.M.	DIRECT BELT OR GEARED	SIZE OF GENERATORS	KVA OR H.P.	AC OR DC	APPROX. ENGINE FACTOR	KIND OF FUEL & SOURCE	SP. GR.	B.T.U. PER POUND	PRICE OF FUEL CENTS/GAL.	FUEL	LABOR	MAINTENANCE	SUPPLIES	REPAIRS & MAINTENANCE	TOTAL	CHARACTER OF REGULATION	CHARACTER OF ATTENDANCE NECESSARY	TROUBLE	IS THE PLANT SATISFACTORY TO OPERATE?	REMARKS
1	Central Station - continuous	1905-7-10	3	225	Diesel	V	3	16x24	164	Direct	3-160	DC	50%	Penna fuel	30	19832	30	33	30	05	01	30	99	Good	Best	Some	Very	Steam Engines used to carry Peak Load
2	Central Station - continuous	2 1907 2-1910	4	225	Diesel	V	3	16x24	164	Dir.	2-300	AC	35%	Fuel	19	18200	35	92		024				Good	High Grade	Yes	Fairly	Used about 6 months per year Water power remainder of time
3	Industrial 55 hour week §	July 1910	1	170	De La Vergne	H	2	17x27½	180	Belt	1-50	AC	65%	Penna Fuel	29	19000	23	198	180	056				Good	Medium	None	Very	Jack shaft to be put to direct hammer and generator
4	Industrial - 10 hour day §	Apr 1911	1	125	De La Vergne	H	1	20x34½	155	Belt	1-60	DC	70%	Texas Fuel	27	19500	30	205	000					Good	Medium	None	Very	Widely swinging load
5	Industrial Electric Generation 8 hour day	Feb 1911	1	225	Diese	V	3	16x24	164	Direct	1-160	DC	70%	Texas Fuel	27	19900	30	400	306	044			754	Good	Medium	None	Very	Sea water used for cooling causing some corrosion
6	Refrigerating & Lighting - continuous	Oct 1911	2	120	Diesel	V	3	12x18	225	Belt	2-85 2-Compress.	AC	60%	Kansas Fuel	34	19600	275	280	160	← 090 →	003	533		Good	Good	None	Very	
7	Central Station - continuous *	July 1909	3 3	450 300	Diesel	V V	3 3		150	Direct	6-370	AC	75%	Mexican Gas Oil	38		38	364	321	070	055	132	968	Good	High Grade	None	Very	Gas turbine rated temporarily 300 hors. D. Engines on as extra
8	Industrial Electric Generation 10 hour day	Dec 1909	1	170	De La Vergne	H	2	17x27½	180	Dir.	1-	DC	54%	Penna Residual	26	19500	225	236	371	061	034	151	853	Good	Medium	None	Yes	
9	Industrial 10 hour day	Feb 1910	1	85	De La Vergne	H	1	17x27½	165	Belt				Crude										Good	Medium		Yes	
10	Industrial 11 hour day	Mar 1911	1	125	De La Vergne	H	1	20x34½	155	Belt	1-75 1-9⅜	AC DC		Fuel			315							Good	Medium	Yes	Fairly	Line shaft also drives elevators etc.
11	Oil pumping		1	125	De La Vergne	H	1	20x34½	155																			
12	Industrial Electric Generation 11 hour day	1905	2	75	Diesel	V	3	10½x15	250	Belt	2-60	DC	40%	Illinois Crude	30	13000	23	270	413	071	019		773	Good	High Grade	None	Very	Repair cost not segregated from plant repair charges
13	Central Station - continuous	2-1905 1-1907	2 1	225 120	Diesel	V	3	16x24 12x18	167 225	Dir	2-165 1-85	AC	41%	Illinois Fuel	40	19500	273	260	207	040 ←	055 →	562		Fair	Medium	Some	Fairly	
14	Central Station - 20 hour day		2	225	Diese	V	3	16x24	164	Dir	1-300	AC	80%	Fuel			30	380	290	03? ←	110 →	810		Good		Yes	Not Very	Excessive Fly Wheel required for Parallel Operation
15	Industrial Electric Generation 54 hour week	2 Oct 1906 2 Feb 1910	4	225	Diesel	V	3	16x24	164	Dir	2-150 1-300	AC	73%	Penna Fue	29	19000	31	295	144	045	010	217	711	Good	Medium	Some	Very	
16	Refrigerating continuous		2 1	225 120	Diese	V V	3 1	16x24 21x18	164 220	Belt Direct	2-compress	DC		Fuel	28	19000	40											
17	Irrigation pumping		1 1	180 260	De La Vergne	H H	2 2	17½x?½ 20x34½	200 164	Belt				California Crude	17	18500								Good	Medium	None	Very	Belted to vertical centrifugal pumps
18	Industrial Electric Generation 10 hour day	1-Oct 1906 2-Jan 1909 3-Sept 1910	6	225	Diese	V	3	6x24	164	D.	6-165	AC	83%	Penna Fuel	28	19243	275	283	176	089	070	090	703	Good	Medium	None	Very	Very steady load
19	Central Station - continuous §	1911	1	170	Diese	V	3	14x21	200	Belt		AC	25%	Missouri Fuel	19	18000	356	339		049				Good	Medium	None	Very	
20	Central Station continuous	Aug 1910	1	225	Diesel	V	3	16x24	164	D.r	1-200	AC	28%	Illinois Crude	25													
21	Mining Plant continuous §	Feb 1911	1	125	De La Vergne	H	1	20x34½	155	Belt			64%	Kansas Fuel	27	19000	130	118	408	018 ←	087 →	1411		Fair	Medium	Some	Very	30 miles from railroad
22	Industrial Electric Generation continuous	July 1907	3	225	Diesel	V	3	16x24	168	Dir	3-150	AC	80%	Fuel	31		25	245	161	← 030 →	070	506		Fair	Best	Yes	Fairly	Engines overloaded easily to 1500
23	Industrial		1 1	35	Hornsby Akroyd	H H	1 1	12x16 14x20	260 220	Belt							25 35							Good	High Grade	None	Very	
24	Water pumping																							Fair	High Grade	Yes	Not Very	Steam plant kept in reserve as Oil Engines are at present
25	Industrial Electric Generation continuous §		16 6	225 225	H-A Diesel	H V	1 3	27x36 16x24	150 165	Dir	15-175 1-300	DC	75%	Texas Fuel	27	19000	266	295 184	150 150	← 050 → 060 →	200 330	693 644		Fair	High Grade	Yes	Yes	Practically duplicate Steam plant as the works are run by electricity
26	Central station 131 hour week	Jan 1911	1		De La Vergne												210							Good	Medium	None	Very	
27	Industrial Electric Generation continuous	1908	16	225	Diesel	V	3	16x24	164	Dir	8-300	AC	73%				23	189	121	032 ←	010 →	352		Good	High Grade	Very Little	Very	ALM "Power, Aug 22, 19
28	Water pumping continuous	Mar 1910	1	125	De La Vergne	H	1	20x34½	155	Belt	2 Turbines Pumps		32%	Colorado Fuel	32	19530	30							Good	Medium	None	Very	
29	Industrial Electric Generation 10 hour day		1	85	De La Vergne	H	1	17x27½	164	Belt		AC	85%	Penna Fuel			325							Good	Medium	Very Little	Yes	
30	Industrial Electric Generation Base continuous load		6	225	Diesel	V	3	16x24	164	Dir		AC DC		Texas Fuel	29	19500										High Grade	Very Little	Yes	
31	Central Station continuous	Sept 1907	2	225	Diesel	V	3	16x24	164																			
32	Central Station - continuous	Jan 1910	1	120	Diesel	V	3	12x18	225	Belt	1-75	AC		Indiana Fuel			30							Fair	Med	None	Yes	Used as auxiliary to steam plant where fuel supply is very uncertain
33	Central Station - 12 hour day	Feb 1906	1 1	170 225	Diesel	V	3	14x21 16x24	200 164	Belt		AC		Illinois Fuel	29	19000	35							Good	High Grade	None	Yes	Used for city light ng
34	Industrial Electric Generation 10¼ hour day		1 1	225 120	Diesel	V	3	16x24 12x18	165 220	Dir	2-85 1-80	DC	48%	Illinois Fuel	30	19200	22	25	55	05	32	14	1310	Good	Medium	None	Very	Widely swinging load
35	Industrial - 15 hour day	Dec 1910	1	90	De La Vergne	H	1	17x27½	180	Belt			78%	Illinois Fuel	29	19000	35							—	Medium	Some	Very	3 Engine replaces Central Station service
36	Oil pumping - continuous	Feb 1911	1	85	De La Vergne	H	1	7x27½	180	Dir	Triplex pump			Illinois Fuel	32	19100											Very	
37	Central Station continuous	Dec 1905 Nov 1910	2 1	120 225	Diesel	V	3	12x18 16x24	225 170	Dir	2-85 1-200	AC	50%	Illinois Crude			20	251	330	← 083 →	500	1163		Fair	High Grade	Very Little	Yes	60~, 2Φ, current
38	Industrial Electric Generation continuous	1910	2	195	Diesel	V	3	14x21	200	Dir	2-120	DC	60%	Illinois Fuel	29	19000	40	501	278	← 103 →	049	931		Good	High Grade	Some	Yes	

These data have been given on the B. H. P. Hour basis and are therefore represented by italics. All others are per Kw-hour.

opinions, although it should be understood that they are not necessarily a criterion of the operation of new designs developed by the manufacturers, and it therefore remains to be determined whether some of the criticisms made will be entirely removed in future installations of these types of engines.

All cost data have been reported as they have been submitted to the Committee. In the records of a few plants there appear to be some inconsistencies in the values given in columns under "Operating Costs," due probably to inaccuracies of either measured or estimated oil consumption or delivered power or both.

Thus far it has been the usual practise in this country to build the Diesel engine of the vertical type, while the hot-bulb De La Vergne engine regularly employs horizontal frames. This has been indicated in column 6.

The load-factor given in column 13 may be more properly termed engine-factor, by which is meant the average per cent of load carried by the engine during the time in service. In other words, the number of hours in operation per day have been disregarded in denoting the load-factor. This course has been pursued as the oil-engine plant suffers no stand-by loss when not in use.

In column 14 the grade of oil has been variously designated as reported by the consumer or user.

All figures in italics represent cases where the detail power cost has been given on the horse-power basis.

Column 17 furnishes an interesting study of the wide variation in price of oil obtaining, due to locality and demand.

Past history has shown that oil is periodically raised in price, and the general tendency at this time indicates that the cost of this product will be somewhat advanced during the next few years.

In view of the other work covered by this year's program of your Committee, no attempt has been made to procure corresponding operating data from the producer gas-power plants, although this information would manifestly be of much interest in connection with the oil-engine data herewith reported. For immediate comparison, data collected by the Power Plant Operations Committee of the Gas Power Section of The American Society of Mechanical Engineers will be found useful, and these are contained in the 1911 *Proceedings* of this society. In this

same volume some results of natural gas-engine costs are published. It is recommended that careful plant records be kept. The Plant Operations Committee referred to above has prepared in a very able manner suitable log sheets for this purpose, and these may be found in the *Proceedings of The American Society of Mechanical Engineers,* and blanks obtained from that society. A corresponding scheme may be employed for steam stations.

REMARKS ON OIL-ENGINE OPERATORS' EXPERIENCES

There have been registered by the operators several criticisms of oil engines regarding minor troubles, but in no case has there been any serious complaint made, with the exception of a few instances where breakages were directly traceable to the inexperience of the operators, or the possible inadequacy of the earliest designs. Pistons and piston rings have been most prominent in the difficulties experienced with the engines, more particularly with the high-pressure type. The carbonization and consequent sticking of the piston rings on either very light or very heavy loads is a constant source of trouble, as is also the rapid wearing down of rings and cylinders, necessitating re-boring about every three years, and reported as due either to faulty lubrication or lack of a cross-head in the use of trunk-type pistons.

The low-pressure type has been more or less free from difficulties but has suffered from carbonization of oil in the vaporizer, as well as a tendency of the engines to loosen on their foundations. In either type of oil engine, where the engine has more than one cylinder, great care must be exercised in correctly aligning the crank shaft and equalizing the work done by each cylinder. If these points are not regularly checked up, liability of springing or damaging the crank shaft exists. In practically all cases the regulation has been reported to be very satisfactory. The way in which regulation is gauged in most of these small plants is likely to differ from what would be demanded in the larger central stations. It is to be noted, however, that one central-station company operating six Diesel 60-cycle units has maintained very good service. Where the low-pressure oil engine is installed there does not seem to be the same stress placed upon the necessity for high-grade attendants. This is

possibly due to the character of service deemed satisfactory where they happened to be used. In plants with engines of the high-pressure type it appears to be an almost unanimous opinion that skilled operators should be employed. The valves must be frequently re-ground to prevent loss of efficiency and capacity through leakage. There are other small adjustments which require attention to maintain the original quality of the engine. Good mechanics or steam engineers may be trained to operate oil-engine plants (special reference to the high-pressure type) satisfactorily, but they should in every case be properly instructed on the adjustment and function of each part as well as in the underlying principle of the engine. It is patent that machinery, no matter of what nature, will, when subjected to operating stresses and wearing action, require (irregularly) replacements and repairs of certain working parts. It is not with the intention of presenting an unfavorable aspect of the oil engine that the list of troubles is made, but on the contrary, to show that, while they have existed, in no case do they appear to be of a serious nature, and we are led to believe that they are susceptible of satisfactory correction. A more definite understanding of the oil-engine problem will be obtained from this statement and should contribute toward the end of securing even more gratifying results from this type of unit in future installations.

SUMMARY OF OIL-ENGINE RUNNING RECORD

Diesel Type

Plant No.

1. Piston rings wear fast and must be replaced as soon as they leak.
2. Piston rings renewed very frequently and valves ground very often.
5. Many broken valve springs, which are, however, easily replaced.
6. Report no troubles.
7. Troubles reported but not defined and assumed not to be of any consequence.
12. Troubles reported but not defined and assumed not to be of any consequence.
13. Some difficulty experienced with leaky valves, piston rings, lubrication, etc., but nothing serious.
14. No overload capacity. Top of cylinders wear presumably from heat action of gases and engine will not carry full load. Cylinder in 20-hour daily service needs re-boring once in three years.
15. Piston rings replaced occasionally. Trouble with crank case lubrication due to the lubricating oil.
16. Troubles reported but not defined and assumed not to be of any consequence.

Plant No.

18. Troubles reported but not defined and assumed not to be of any consequence.
19. Broken springs, which are, however, easily replaced.
20. Broken springs. Top piston rings wear badly. Pitting and breaking of fuel needles due probably to acidity of fuel oil.
22. Valves and piston rings prone to leak. Poor cylinder lubrication, piston rings being renewed twice a year. Cylinders must be re-bored every three years. Carbonization very bad. Valves reground very frequently—about every ten days.
24. Troubles reported but not defined and assumed not to be of any consequence. Operator would not recommend them for reliable work, as they are apt to be out of order when most needed.
25. Excessive wear on piston and cylinder liners due to improper lubrication. Crank shafts broken due to non-uniform effort from the engine.
32. Troubles in keeping work equally divided between cylinders. Packing in fuel valves hard to keep tight. Injection air pressures must be varied by hand for changing loads.
33. No troubles experienced.
34. No troubles reported.
37. Due to faulty lubrication, the piston rings wear badly and must be replaced about once a year.
38. Troubles reported to be no more serious than those of other types of combustion engines.

De La Vergne Type

3. Report no troubles in 18 months.
4. Lubrication much more expensive than that of steam engines.
8. Report no troubles with engine itself, but air compressor supplying injection air requires frequent attention.
9. Troubles reported but not defined and assumed not to be of any consequence.
10. Owing to inexperience of operators, many delays and breakdowns have occured, although no difficulty has been experienced with leaking valves, etc., unless the parts were cracked or broken.
11. Troubles reported but not defined and assumed not to be of any consequence.
17. Report no troubles.
21. Valves need frequent regrinding. Water jacket cracked due to sudden change in temperature of cooling water.
23. Trouble with crank pin lubrication.
25. Difficulty in keeping frame tight and solid to foundation.
26. Troubles reported but not defined and assumed not to be of any consequence.
27. Troubles reported but not defined and assumed not to be of any consequence.
28. Report no troubles.

Plant No.

29. Very little trouble except that caused by inexperienced labor in packing oil pump and spray valve.
35. Two defective parts replaced by manufacturer.
36. No trouble reported.

OIL PRODUCERS

The gasification of oils for power and fuel purposes is accomplished through partial oxidation, in a manner similar to the action that takes place in the coal-gas producer. Most of the earliest types which have gained any prominence, the Jones, the Amet-Ensign and the Nix-Frost producers or oil-gas sets, depend upon the method of gasification during partial combustion, which aims to generate a clean gas of high heat-value. A more recent type has been brought out, known as the Nells-Grines oil producer, which departs from the preceding designs in that it introduces a bed of coke to aid in eliminating the lampblack or tarry compounds. The process in each type varies appreciably; the first completely burning and chemically converting into CO, through surplus or added oil at the high temperatures obtaining; the second, by incomplete combustion, the fuel being atomized by injection into a vertical oven and mixed with insufficient air under pressure, aided by the introduction of small jets which assist the liberated oxygen in combining with the particles of fuel, establishing CO; the third, distillation of part of the gas by burning the residuum through properly arranged ovens or retorts; and the fourth, passing the products of initial chemical reaction through incandescent coke beds, reducing the CO_2 to CO.

In the Nells-Grines producer the oil is atomized in the upper part of the generator by means of a steam spray and there subjected to partial combustion. The products of this partial combustion pass downward through a bed of incandescent coke in the bottom of the generator, and the heavy hydro-carbons are thereby broken up, the tarry content is "fixed" and the portion of carbon which would ordinarily pass out as lampblack is deposited on the coke bed and replenishes the bed, partly making good the reduction due to gasification of the coke.

Owing to the fact that crude oil is constituted of oils of various flash points and distillation temperatures, the employment of a temperature sufficiently high to convert the entire quantity of the oil usually exerts a deleterious effect upon a large portion of it, with the result that dissociation takes place, precipitating

excessive lampblack. This has been one of the difficulties encountered in the development of the oil producer and has necessitated the extensive cleaning auxiliaries. The producer employing the coke bed aims to overcome this feature.

The claims of efficiency for the various oil producers range from about 39 to 85 per cent. It is believed that very careful manipulations are necessary to hold the producer up to its highest point of efficiency. In reports made somewhat less than a year ago it was observed that the relative power consumption of the auxiliary plant was quite large, and in commercial operation the efficiency was surprisingly low.

Since all the oil-producer developments have taken place upon the Pacific Coast, your Committee has been prevented from familarizing itself with the latest improvements in design.

Descriptions of the first three producers may be found in Nisbet Latta's *American Producer Gas Practice,* and for an outline of the Grines Producer, see *Power,* page 743, November 14, 1911, issue.

In addition to the above remarks we wish to quote from the Wisconsin Engine Company, as follows:

> "We have recently placed on the market an oil producer. The producer consists of a plain shell, fire-brick lined, with a bed of coke at the bottom. It operates on the down-draft principle. The oil is sprayed into the upper zone of the producer by steam jet, and air is admitted at the same point, the issuing gas from low grade oils being ordinarily of the following composition:

CO_2	6.2	CH_4	5.4
O_2	0.3	H_2	4 6
CNH_2N	1.0	N_2	67.4
CO	15.1	B.t.u.	143.0

> We can get from the same apparatus a producer gas of higher heat value simply by changing the manipulation of the producer, and from higher-grade oils we naturally get somewhat higher-heat-value gas; but, as operated to secure gas of the analysis given, the producer is very simple to handle and the gas is remarkably uniform in composition. Further, handled in this manner, expense of cleaning is very slight.
>
> We have had a producer of this type in operation for over a year on 14 degrees gravity, asphalt-base oil, without shut-down, and the producer is often operated for several days at a time without being touched by the operator and without a single adjustment of any nature being made. This plant is installed for irrigation purposes and is on 24-hour service."

IMPROVEMENTS IN GAS ENGINE DESIGN

Your Committee has not attempted in this year's report to enter extensively into the subject of gas engines, which was thoroughly discussed in the 1908 *Proceedings* of the Association. Some effort was made to learn from manufacturers the chief modifications that had been made in their respective designs and probably suggested to them by the further experience gained in operation. The replies have mostly been of a general character, omitting discussions of detail improvements. The Westinghouse Machine Company has, however, submitted to your Committee a comprehensive account of the important changes in their design which, in all likelihood, typify the trend in gas-engine practise and from which the following is quoted:

Improvements in Westinghouse Gas Engines

The Westinghouse Machine Company reports no radical departure in general type of their gas engine which was described in the *Gas Engine Committee Report of* 1908. It has been announced, however, that many detail improvements have been introduced which have resulted in improving both the operating qualities and durability of the engines. The important changes which this company has made are summarized below:

"Uniform throttling governing is still strongly advocated. * * * It has been found very desirable to provide for ready adjustment of gas and air mixtures when in operation. * * *

"The one-piece cylinder with removable jacket has been retained. The cylinder section has been simplified in providing properly located openings with steel-tube bushings for the igniters and air inlets. These improvements not only facilitate the casting of the cylinder without shrinkage strains, but also insure proper metal thickness between jacket and inner cylinder wall. * * *

"The gas port has been placed underneath the air port, and with rich gases a more thorough mixture with the descending air is obtained. Independent pipes are led to the gas and air-inlet cases on two cylinders with the gas and air piping on the opposite side of the engine, and the supply connected at the center of the headers. * * *

"The piston is made in a one-piece casting. * * * The piston is firmly held between a shoulder turned on the rod and a

flange nut. * * * The rods have a water duct bored through the entire length, excepting at the center of the piston, where solid metal is left to serve as a deflector for the circulating water.

"The simplicity of the magnetic igniter trip has much to recommend it both from its appearance and the ease with which this system is applied to the engine. * * * Although the magnetic trip has been used successfully on both low and moderate-speed engines, the time lag in the trip armature due to the reactance in the circuit may retard the point of ignition. * * * In the slow-speed engines, with long stroke, hesitation in the operation of the igniter may not be felt. * * *

"Large slow-speed engines, like the Westinghouse Gary units, have worked ideally with the magnetic system. However, small units above 100 r.p.m. will always receive only ordinary care, and therefore it has become a general policy to include the more positive mechanical device on all new units operating at 100 r.p.m. or above * * *

"A 4-part bearing is used with cap, lower shell, front quarter-box and rear quarter-box. The two quarter-boxes furnish means of adjustment for wear on both front and back of bearings to avoid disturbing the clearance at either end of cylinder in taking up on the bearing. * * * Lower shell has a cylindrical seat and, when the shaft is jacked up, can be rolled about the shaft for removal. Ready inspection of the bearings can be made through two small removable covers.

"A short cross-shaft is used with spur and bevel gearing to drive the lay shaft located on the fly-wheel side of the engine. In this arrangement the width of the engine is kept within smaller limits than formerly. All large moving parts of the valve gear, as well as overhanging gear case, are moved from the crank side of the engine. * * * With twin engines, all moving parts on the inner side can be observed while standing between the engines.

"Hunting-tooth action is secured in the train of gears, in which a final reduction of 2 to 1 is obtained. This produces greater uniformity of wear than would otherwise be possible, owing to the different points of stress in the gear due to the time of valve openings. * * *"

The following manufacturers did not refer to details of design or to business undertaken, but expressed their opinions

on the oil and gas-engine situation, for which the Committee is indebted. It has, however, been impossible to quote them owing to lack of space:

Allis-Chalmers Company.
Ansler Gas Power Company.
The Bethlehem Steel Company.
C. & G. Cooper Company.
Fairbanks-Morse Mfg. Company.
Minneapolis Steel and Machinery Company.
National Meter Company.
Snow Steam Pump Works.

DEVELOPMENTS IN THE COAL PRODUCER

Gas power has been accorded considerable recognition during the past few years, but not, however, in full measure with all that had been claimed for it when the apparatus was introduced. There were a great many manufacturers influenced by the attractive fuel economies of the gas producer and engine, and a correspondingly great variety of designs was placed on the market. The success attending the various types has evidently been of a different order, such that we have witnessed the withdrawal of several of the manufacturers from the gas producer and engine field, leaving only those who have sufficiently perfected the details of their designs.

Those producers for use with anthracite fuel have in the main become standardized and have given uniform satisfaction where installed. Bituminous producers require more thought in design and operation, and the results obtained from those producers that have been well designed and which embodied the principles necessary to adapt them to the use of this fuel have, as a rule, given favorable results. The cause of the dissatisfaction in places where producers were installed for handling bituminous fuel, was the fact that they were not designed for the use of this fuel.

The producer and gas engine, however, is rapidly finding its place in this country, and there will always be a demand for units where the installations are of moderate size, not exceeding 2000 or 3000 kw plant capacity, and where the plant has a high load-factor. This is particularly evident in localities where solid fuel only is available, and comparatively costly, exceeding for instance, $3.00 per ton. For lignites, this type of equipment is particularly advantageous, as the progress in the burning of this

grade of fuel on boiler grates has not thus far been very marked. While much thought has been given to peat and other low grade fuels, the Committee finds nothing in the way of practical use of these to report at the present time.

The following are quotations from manufacturers' communications:

The Westinghouse Machine Company

"At the time the Committee's Report of 1909 was published this company had just completed its long series of experiments with the double-zone type of producer designed to obviate the use of double generators worked in series but alternately operated, and the elimination of tar extractors.

"Since that date we have placed in actual service in different industries a total number of 47 of this type of producer, aggregating 12,750 hp. For small central-station power there have been 20 units installed, representing a total of 5500 hp. The same principle as employed in the design described in the 1909 report has been retained, but improvements in the nature of vaporizer and tuyere construction have been effected, which had been suggested by varying conditions met with in regular practise. The coals gasified at the different plants vary widely and embrace the following: Cumberland, Pocahontas, Colorado bituminous, Pittsburgh, Alabama and Wyoming bituminous fuels.

"It has been found that coals not containing more than 20 per cent ash and 2 per cent sulphur occasion no difficulty in operation. No appreciable amount of clinkers is produced, as only low temperatures prevail. Either caking or non-caking coals may be gasified in this producer; the former, however, will obviously require more regulation of the fire beds."

The Wisconsin Engine Company

"This is a period in which the producer gas plant is finding its place. We note a steady demand for anthracite producers of the angle-of-repose grate type, to use the smaller sizes of buckwheat fuels.

"We offer for bituminous fuels a down-draft producer, water-sealed type, with a central cone through which the producer is stoked by the introduction of a weak mixture of air and gas, which burns as it issues from the pipe and is not subjected to the danger of explosions such as have occurred with down-draft

producers in which compressed gas has been forced back into the fuel body to make an explosive mixture with the residual air at the top of the producer. We refuse to bid on this producer under any circumstances where we have not had an opportunity to test 50 to 100-lb. samples of the fuel in the miniature plant which we have at the works."

The Smith Gas Power Company

This company reports that it has recently made a number of installations of gas producers for electric lighting service. These machines are all operating on anthracite coal, excepting two Texas installations which are operating on Texas lignite. For a detailed description of their gas producers they refer to their Bulletins, in which they describe two types, one operating on bituminous coal and the other on pea anthracite coal.

The Seager Engine Works

formerly the Olds Power Company, state that they have placed a number of gas producers and engines for use in electric generation, but have given no detailed information regarding these installations.

THE HUMPHREY GAS PUMP

The gas pump invented by Herbert A. Humphrey, of London, in 1909, was exhibited in Brussels in 1910 and created much comment on account of its extremely simple design and the originality of its operation.

This gas pump utilizes the energy of a combustible mixture of gas and air to raise a column of water from a lower to a higher level, and employs the motion of this column to control the pump. The mass of water, which is large and moves at a relatively slow velocity compared with the piston speeds of small engines, but at a high velocity compared with pump piston speeds, acts as a pendulum, which swings between the gas-combustion chamber and the outlet tank, and this water, by its movement alone, draws in and discharges water to be pumped. It also draws in the explosive gaseous mixture and compresses this mixture previous to ignition, exhausts the burnt products and again draws in a fresh charge of combustibles.

In the accompanying cuts the construction of the Humphrey pump is shown diagrammatically. Fig. 8 represents the con-

struction when pumping against low heads of water, while Fig. 9 represents the construction when pumping against high heads. Supply tank S T, water-inlet valves W, discharge pipe D and the elevated tank E T are common to both pumps. In the case of the low-head pump, water is to be raised from S T to E T. C is the combustion chamber fitted with inlet valve I and exhaust valve E. By means of a simple interlocking gear, valves I and E are so connected that both cannot be open at the same time.

The cycle is as follows: The charge of gas and air under compression in the combustion chamber C is fired by a spark-plug. All valves are shut before explosion occurs, and the water is

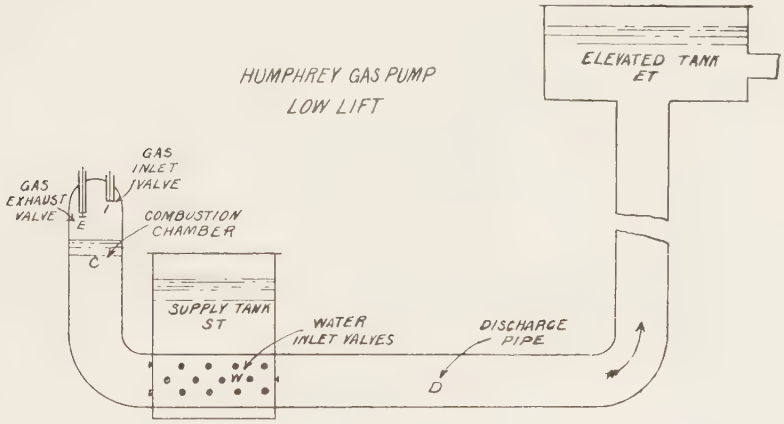


Fig. 8

driven downward in the pump and elevated to E T. The column does not stop when the pressure in C has reached that of the atmosphere, but continues below atmospheric pressure by reason of the inertia of the water column. This causes inlet valves W to open, drawing in a fresh supply of water. After coming to rest, the water flows back into C, closing W, and on reaching E closes it by impact, expending the rest of its energy in compressing the remaining burnt gases. This pressure reacts on the water-column, driving it down, again going below atmospheric pressure, when I opens and a fresh charge of combustible is drawn in. After coming to rest again, the water compresses the charge, which is ignited, and the cycle repeated.

In the case of the high-head pump, water is forced into the compression cylinder X. When this pressure equals the head to which it is eventually forced, the valves Y open and the water is forced up through the discharge pipe D. On the return stroke,

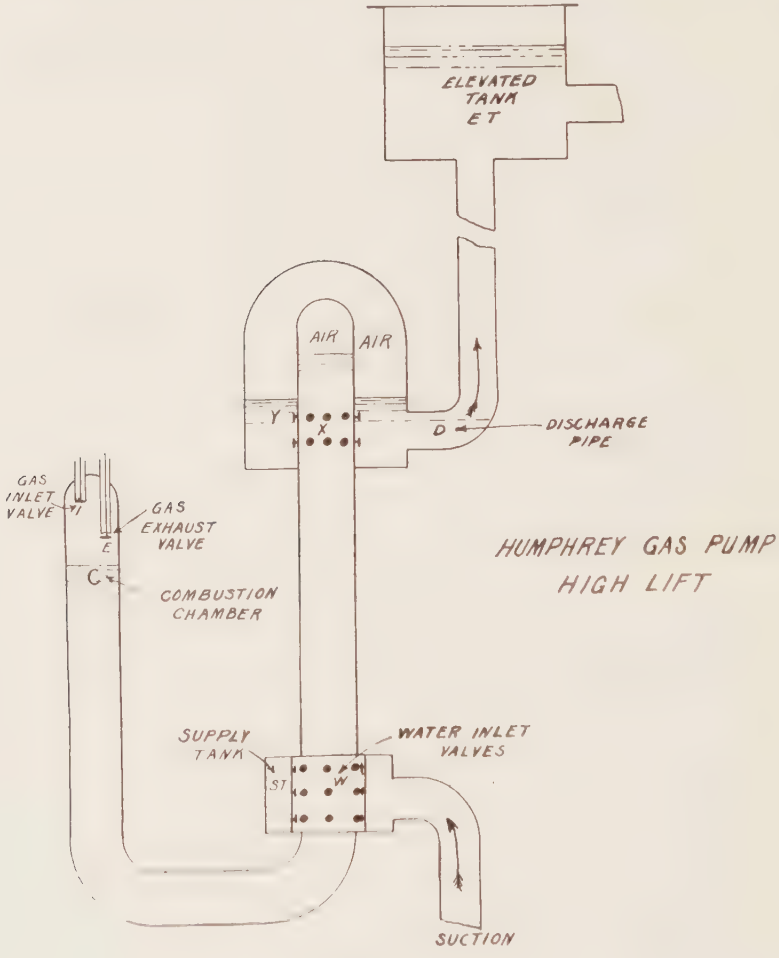


Fig. 9

the valves Y immediately close and the air in the cylinder X expands until the pressure is below that of the suction head, when the valves at W open and a fresh supply of water is taken into the pump.

When the pump is to be used against low heads, the combustion chamber is placed a considerable distance below the supply tank, thus obtaining a high working pressure and consequent increase in efficiency.

On shutting off the spark the pumps stops, and if on the compression stroke, may be sometimes started again by simply turning on the spark; this often fails, in which case the pump is started either by pumping a charge of compressed air into the gas cylinder or else by priming with gasoline and thus forming an explosive mixture.

A 2-cycle pump has been experimented with, but up to the present time has not demonstrated an efficiency great enough to warrant further experimentation until the 4-cycle pump has been further developed. A double-barrel pump has been contemplated but nothing has been done towards developing it.

The Humphrey pump has been given many theoretical efficiencies and there is no doubt, when the larger units are constructed, that a high thermal efficiency will be obtained. From actual trials to date thermal efficiencies of 15 per cent have been obtained in units as small as 2 hp, and of 22 per cent with units of 40 hp capacity.

The advantages claimed for the Humphrey pump are:

First.—Simplicity of construction and low maintenance cost.

Second.—Cylinders and exhaust cooled by the water pumped, resulting in freedom from troubles due to expansion and contraction of working parts.

Third.—The small amount of lubrication required, due to the lack of high pressure on any working parts.

Fourth.—High efficiency, due to utilization of the expansion of the gas to atmospheric pressure.

Fifth.—Simplicity in regulation, the pump adapting itself automatically to changes in head pumped against.

Sixth.—Ease in starting and stopping.

The progress of installation of Humphrey pumps has been somewhat slow, and the reports received from time to time are the result of tests on experimental machines. There has been only one contract placed in England, an installation of 20 hp pumping against a head of some 30 ft. The Siemans Schuckertwerke Company, German licensees, are building a unit of 1000 hp, which they estimate will have a thermal efficiency of 35 per

cent. This unit, however, will not be ready to run for some time.

The Humphrey Gas Pump Company, of Syracuse, N. Y., have acquired the American rights and have experimental pumps in operation. They have succeeded in pumping water against a head of 100 ft., exceeding by 60 ft. the results claimed for any foreign installation. This company has taken a contract to install a Humphrey gas pump for the Semet-Solvay Company, at Detroit, Mich., capable of pumping 2500 gallons of water per minute against a head of 90 ft.

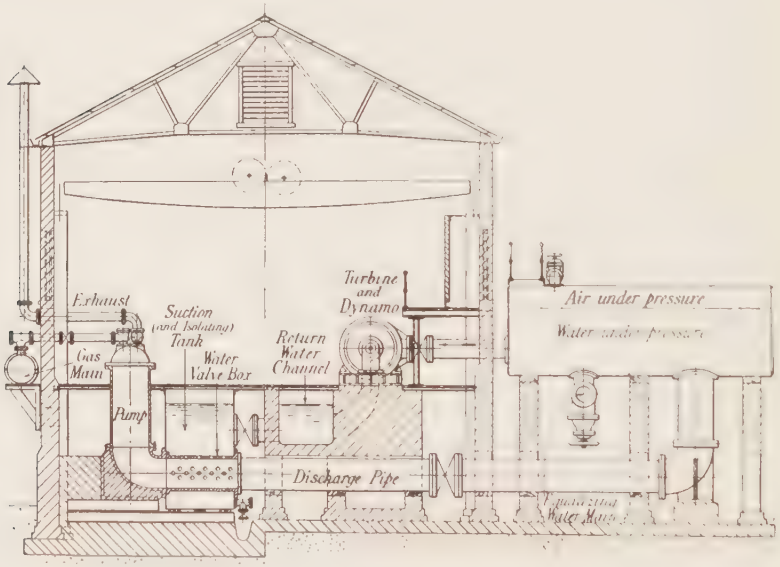


Fig. 10

The most advantageous application of the use of the Humphrey pump to-day seems to be for pumping water in large quantities, which would make it especially suitable for water supply and irrigation purposes and sewage pumping. The Humphrey pump has many possible opportunities for commercial adaptation. Its use has been mentioned in connection with the water turbine direct-connected to generators for central-station lighting and also in connection with blowing plants and for compressing air. Several articles have been written describing how this reciprocating action can be applied to a rotating element. The accompanying cut (Fig. 10) shows a

proposed adaptation of the Humphrey gas pump to the generation of electricity for central stations. This scheme was shown in a paper presented by the inventor, read before the Institution of Mechanical Engineers in London, in November, 1909.

NATURAL GAS

The pumping of natural gas throughout the United States has increased steadily since its finding, and, although some of the eastern fields have been depleted, new fields are being found and developed by improved methods of drilling, and we may look for a continuance of the supply for many years to come, especially since its use is being conserved for strictly legitimate purposes.

When natural gas is available for the development of power, its use in the internal combustion engine is recommended. This is preferable to using it as a fuel for the generation of steam for use in steam prime movers. In a gas engine, efficiencies in the neighborhood of a kw-hour for 15 to 18 cu. ft. of natural gas can be obtained, whereas, in the generation of steam, efficiencies of only a kw-hour for 30 to 50 cu. ft. of gas are obtainable, depending upon size. Where the gas is transported for any great distance at a considerable cost, this increase in efficiency cannot be overlooked in utilizing the gas for the generation of power. Natural gas is an ideal fuel for gas engines, as it allows a maximum capacity per cubic foot of piston displacement, is rich in heating value, slow burning and stands high compression without premature firing. Its heating value varies from about 825 to 1150 B.t.u. per cu. ft.

The following statistics will show briefly the location of the natural gas fields and its production for the year 1910, as reported by the Department of the Interior in *Mineral Resources.*

Non-Metals

1910—NATURAL GAS PRODUCTION

West Virginia	191,000,000	M cu. ft.
Pennsylvania	127,000,000	"
Ohio	48,000,000	"
Kansas	59,000,000	"
Oklahoma	50,000,000	"
New York	6,000,000	"
Indiana	6,000,000	"
Gulf States	8,000,000	"
Illinois	7,000,000	"
Kentucky	1,000,000	"

California	3,000,000	M cu. ft.
Ark.-Colo.-Wyo.	3,000,000	"
Miscellaneous	110,000	"
	509,110,000	"

NOTE:—It is understood, of course, that the value of natural gas to the operator depends upon the location of commercial gas pipe lines.

UTILIZATION OF GAS OR OIL-ENGINE WASTE HEAT

As less than one-third of the available heat in the fuel supplied to the internal combustion engine is ordinarily converted into mechanical work, the remaining major balance appears about evenly divided between the heat discharged to the exhaust and that absorbed by the water-jackets. The recovery of as much as possible of these two last items is naturally of appreciable engineering interest. Since the outlet temperature of the jacket water is comparatively low, 150 degrees* and less, it does not possess much value for ordinary uses. If gas engines should be operated in conjunction with a steam-power plant, the heat led away by the jacket water might be successfully conserved through boiler-feed systems. Through the introduction of the heater or boiler in the path of the exhaust gases, a quantity of steam may be generated. This averages roughly 2 lb. per brake horse-power developed in the main unit, and in round numbers this is but one fifteenth the water circulated through the jackets. Exhaust heaters are now being frequently installed where this small percentage may be profitably applied in a gas-power plant. Such a heater should be constructed of cast-iron in order to resist corrosion and be properly designed to avoid creating a back pressure on the engine.

The project of operating a low-pressure steam turbine on the waste heat of a gas engine has been advanced for some time, and for large plants such a plan offers very interesting possibilities. Although no definite progress has been made in this direction the report is current that some large gas-engine users are contemplating its adoption. An extended discussion of the features involved and the probable results of operation appears in *Power*, April 11, 1911.

* Usual American Practise.

GAS TURBINES

The gas turbine is periodically a subject of comment and investigation, as it is thought that its successful development would bear a relation to the reciprocating gas engine corresponding to that now existing between the steam-piston and turbine motors. Its progress at present is restrained principally by two obstacles; first, the difficulty of establishing an efficient cycle of operation, and second, the production of constructive materials which may withstand both the heat and chemical action of the gases and the centrifugal forces developed in the revolving element. Experimental gas turbines as large as 1000 hp have actually been built and operated. However, positive information of their true economy and reliability has not, up to the present time, been brought forward. For partial reference to the theory of the gas turbine, see a book prepared under the same subject by Henry Harrison Supplee, 1910; also refer to *Power*, page 191, February 6, 1911.

ALCOHOL ENGINES

At the present time the use of alcohol engines is restricted by the high tax or expense of alcohol. The Government has conducted elaborate experiments to determine the economy to be obtained by burning this grade of fuel, and the tests are described at length in their Bulletin No. 392, *Gasoline and Alcohol Tests on Internal-Combustion Engines.*

They show that by employing higher compression pressures (150-200 lb., whereas the gasoline engines in the main use 70-90 lb.) very good economy may be obtained, approximately .7 lb. per B.t.u. hour, which is fully comparable with the gasoline engine. The thermal efficiencies of the two engines are about equal under the same operating conditions, but that of the alcohol engine may be nearly doubled by using higher compression. These facts are shown in the table on page 34 of the Bulletin previously referred to. As long as the high price of alcohol continues, this fuel will take no important part in the production of power. There is this, the Committee feels may safely be said: With the development of an industry of some magnitude extracting alcohol from shrubbery and other vegetable matter through fermentation, there will be established an innovation where natural fuels are costly.

PARTIAL REFERENCES TO RECENT ARTICLES ON OIL AND GAS-ENGINE SUBJECTS

There has been much published regarding oil and gas engines and producers. The following articles are listed as they appear particularly worthy of noting. Those whose interest may carry them further into the subject will find a valuable running index in the *Journal of The American Society of Mechanical Engineers*, prepared by the Literature Committee of the Gas Power Section:

Oil Engines, by H. R. Setz, *A.S.M.E. Journal,* October, 1911, page 1169.

Test of an 85-hp Oil Engine, by Forest M. Towl, *A.S.M.E. Journal* November, 1911, page 1351.

Résumé of Producer Gas Investigations, 1904-1910, by Prof. R. H. Fernald and Carl D. Smith, *Bulletin No.* 13, U. S. Bureau of Mines.

Producer Gas Power Plant Development in Europe, by Prof. R. H. Fernald, *Bulletin No.* 4, 1911, *U. S. Bureau of Mines.*

Topical Discussions of Blast Furnace Gas Power Plants, by A. E. Maccoun, *A.S.M.E. Journal,* September, 1911, page 1071.

The Development of the Land-Type Oil Engine, by Dr. Von A. Nagel (Germany), *Zeitschrift des Vereines Deutscher Ingenieure,* August 12, 1911, page 1318.

Suction Gas Engines and Producers, by W. A. Tookey, *The Mechanical Engineer,* September 15 and September 22, 1911.

International Combustion Engines Working on the Diesel Principle, by H. L. Howard, *Proceedings of Institute of Electrical Engineers* (Greater Portion 1911 Abstract)—*The Electrician,* June 30, 1911, page 454.

Internal Combustion Engines for Power Stations, by R. M. Carr, *Proceedings of Institute of Electrical Engineers* (Greater Portion 1911 Abstract)—*The Electrician,* May 30, 1911, page 458.

CLOSURE

In closing your Committee desires to point out that, owing to the Convention being held this year in Seattle, it has been necessary to complete the Committee work much earlier than usual. For this reason some of the investigations are not as complete as they would otherwise have been. Your Committee hopes for a full and free discussion of the Report, and especially wishes to hear freely from our western members.

The work of preparing this Report has been greatly facilitated by the very cordial co-operation and help received from numerous manufacturers, engineers and operating companies. To enumerate all these would entail a long list, but your Committee desires to make suitable acknowledgment for the help received from them and to most sincerely thank them for the service they have rendered.

Respectfully submitted,

Committee
- I. E. Moultrop, *Chairman*
- W. L. Abbott
- F. N. Bushnell
- E. D. Dreyfus
- John Hunter
- R. S. Kelsch
- J. B. Klumpp
- W. N. Ryerson

DISCUSSION

Mr. B. J. Denman, Detroit, Mich.: I wish to refer to that portion of the report on page 487, which covers the use of large boilers at Detroit and in which the high efficiency attained was attributed to carefully selected fuel and skillful firing, rather than to the design of the boiler. As a matter of fact, with the exception of two or three of these tests in which a special fuel was used at the request of the Semet Solway Company, which assisted in the test, the same fuel was used that is found most economical for regular service and the boilers were operated during the test by the regular boiler-room force.

There is no question that the high efficiency obtained was due to the design of the boiler, which provides an unusually large combustion chamber, a very long pass of the gases before they come in contact with the heating surface and very small radiation and infiltration losses on account of the relatively small amount of enclosing wall surface. The large grate area also contributes in a considerable measure to the high efficiency on account of reducing the number of edges of the fire and the consequent reducing of the air infiltration at this point and making for a more uniform fuel bed, and, also, the boiler being

double-end fired, one side will make up for the sins of the other.

Not only was the efficiency high on these tests, but under regular operating conditions it will approach test efficiencies much more closely than the ordinary small boiler, because the fireman can maintain much more uniform conditions in one large fire than he can with five or six fires under the same capacity of boilers. Because of the elimination of bridge walls and arches and a reduction of the area of the side walls, the cost of maintenance of furnaces is very greatly reduced.

The efficiency curve of the boilers is very flat, dropping from 80 per cent at slightly less than rating to 74 per cent at 200 per cent of rating, and this will greatly reduce the number of boilers necessary to meet winter peak loads. There are two boilers for each 14,000-kilowatt unit and each boiler can easily carry 8000 kilowatts continuously. The use of two boilers per unit simplifies the piping system very greatly and reduces the investment in and the cost for maintenance of the piping system in a large degree.

The cost per horse-power of the boilers themselves is about the same as the cost of the smaller boiler; but there is a marked reduction in cost of the setting, buildings and pipings; and the large boiler also makes a particularly good arrangement of boiler-room basement because of the small number and the wide spacing of the boiler columns.

Mr. P. Junkersfeld, Chicago, Ill.: There are one or two points concerning this report to which I would like to refer. One is the steam-flow meter. I do not believe that subject can be emphasized too strongly. The electrical industry has been developed within the short period of 30 years. This has been made possible in a considerable degree because of the availability of electrical measuring instruments almost from the start. Steam production is two or three times as old, but the necessity for such instruments was never so urgent because there were many physical manifestations by which one could judge about what he was doing. During the past few years, while we have been getting down to greater refinement of operation and it has become necessary to watch expenditures more and more closely, the necessity for these steam meters has become much more apparent. There is no reason why steam generation and operation should not be carried on with a great deal more accuracy

and definiteness, so as to reduce the losses in the various elements of the system. For instance, with a whole bank of boilers working together and no meters of any kind, it is largely a matter of guesswork as to what the individual boilers are doing, and the time for guesswork in steam generation is rapidly passing away because of the availability of steam flow meters.

Another point I would like to call attention to is discussed on page 497, the self-contained units. That subject needs considerable thought and further knowledge. It is just as necessary, perhaps more necessary, to know what the power user to whom we are trying to sell power can do as what we can do ourselves in our own boiler and engine rooms. In this day of automobiles and other intricate machines, mechanical knowledge and mechanical experience are spreading very rapidly, and some of the old objections of cost and of the uncertainty as to high-grade attendance are, therefore, lessening. They are not as useful as talking points when negotiating with a power user. I would suggest that next year's administration, either through committee reports or otherwise, arrange that we may have operating records on economy and reliability as complete as possible for some of these units, so that when we talk with a prospective power user who has these high-efficiency, self-contained units in mind we may know somewhat better than he what it is possible for him to do.

Mr. C. W. Stone, Schenectady: There are just a few words which I would like to say in regard to the steam-flow meter. The device has made it possible to check results in the boiler-room, and this should give us very important data.

The first application of the steam-flow meter was on the steam-heating system of the Schenectady works of the General Electric Company. Soon after the installation of these meters it was noted that the amount of steam furnished for the heating system was greatly in excess of that required for heating, and an investigation followed which showed a number of leaks in the piping system to the buildings through which a large amount of steam was escaping. It was estimated that the amount of steam which had escaped through these leaks represented an annual expense of several thousand dollars—enough, in fact, to pay for equipping the entire piping system with flow meters.

The next move was to use one on each of the boilers in the boiler-room. After this installation it was soon observed from

the automatic, or so-called automatic, action of the water-level feed that the output of the boilers would vary from about 10 per cent of normal to 200 per cent of normal in a few seconds. This could result only in tremendous strains in the boiler itself and in the supports for the boiler. A rearrangement was made of the automatic boiler-feed, so that the output could be held constant. Steam gauges, of course, would not give any indication of such changes in boiler output. If the boiler output can be kept constant there must result economy in the production of steam as well as in the maintenance expense of the boilers. Each boiler of the bank in both power-houses is now equipped with an indicating flow meter. If we are justified in installing ammeters or indicating wattmeters with generators, we are certainly justified in furnishing for use with boilers some device which will indicate the output.

The report mentions another device which to my mind is one of the most fundamental inventions of the age, and that is the Humphrey pump. The applications of this pump are many. The Germans and the English are following this very closely, and I trust the Committee will keep in touch with the developments of the coming year and give us a more complete report next year of this very interesting machine.

Mr. George Harding, Cœur d' Alene, Ida.: I would like to inquire if any investigation was made as to grease extraction from exhaust steam, and whether any satisfactory mechanical means have been found of getting rid of hardness in water other than by chemicals.

Mr. Ludwig Kemper, Albert Lea, Minn.: I would like to ask if the Committee has heard of any oil engines in sizes of 750 to 1500 horse-power in use in this country, and to get their opinion on oil engines as to reliability and continuity of service in central stations, where it is quite important that the service be not interrupted.

Mr. R. D. De Wolf, Rochester, N. Y.: I would like to ask if the Committee has made any investigations regarding the velocity of steam which is used in designing the pipe lines in a generating station. Under the old practise, with a pulsating flow of steam it has been customary to use five to six thousand feet. With turbines, that can, perhaps, be greatly increased, and I would like to know if any investigations have been made to find

out what the limit is, and what the reasons are for limiting the velocity at any point.

Mr. T. H. Yawger, Rochester, N. Y.: The question of using oil as a fuel was touched upon very lightly in this paper. I would like to ask if the Committee has made any thorough investigation of that matter? We get a great many reports of oil-burning equipment, saying it takes about three per cent of the volume of steam the boiler generates to vaporize the oil. We tried the experiment a short time ago of equipping one of our smaller plants with oil burners for peak purposes. We put in a standard oil-burning setting under boilers with calorex vaporizing apparatus and had difficulty in keeping up steam. On looking the situation over very carefully, we found that we were pumping a whole lot of feed-water into the boilers, but still had difficulty in supplying enough steam to our prime movers.

We then called in an expert from the Standard Oil Company to instruct us as to the proper method of vaporizing the oil. He said our burners and setting were all right, but that we would have to be satisfied if we could vaporize the oil with about 20 per cent of the amount of steam the boiler would generate, which statement was borne out by our experience; that is, the harder we would crowd the boilers the more steam it would take to vaporize the oil. In fact, we had a kind of short-circuit around there, and we could not supply the prime movers with the amount of steam necessary to carry the load.

There have been many tests made, and I have read about the efficiency of these oil-burning equipments where tests have been made in the west, but those tests have not been borne out by our experience. That is the ordinary every-day experience that many of us run up against, and I think the question will bear considerable further investigation.

Mr. J. A. Lighthipe, Los Angeles, Cal.: Practically all the plants in Southern California burn crude oil as fuel. The average steam consumption to atomize the oil under a first-class burner approaches two or two and one-half per cent. Some of them reach as high as five per cent, but a good burner, carefully handled, can easily vaporize or atomize all the oil necessary on about two and one-half per cent of the total steam used. We are experimenting now with mechanical burners and expect to reduce that to close to one per cent.

Mr. L. H. Egan, Kansas City, Mo.—In one of our power stations, in fact, in several stations, some electrical and some steam generation, we have about 8000 horse-power of boilers under which we have oil-burning equipment. A year or two ago a test was made and showed that we were using approximately five per cent of the steam generated for the oil-burning quipment. Last year in the *Electrical World* a statement was made under the subject "Résumé of the Oil-Burning Business," that in some cases as low as one per cent was used. We tried our best to find out where these were, but were not successful in getting satisfaction, either from the *Electrical World* or from the parties to whom they referred us as using these mechanical-burning equipments. We found as a result of the tests that it generally takes about five per cent of the steam generated.

Mr. J. B. Walls, Baltimore, Md. (submitted in writing):

Water-Power Prime Movers

Vertical Hydraulic Units

In certain cases, horizontal-shaft turbines could have been used advantageously in plants of about 50-ft. head, where double-runner vertical units were actually installed. Such a vertical unit of large capacity has disadvantages where the concrete structure of the power-house forms the turbine casing. In this event much of the fitting work of the turbine parts cannot be done at the factory and must be done at site, necessitating handwork in more or less dark, damp and crowded pits, or the hauling back onto the main floor of the heavy pieces to enable the chipping, etc., to be done there, thus lengthening the time required for installation and increasing the expense.

The work of installation is slow, since it is impossible to work at many points of the unit at once, seeing that the lower parts of the turbine have first to be set up, then the middle and then the upper portion. When these parts are in alignment they must be marked for drilling, then dismantled and the shaft and runner installed. Finally these parts must be reassembled and bolted together, and only after this can the setting up of the generator be commenced. All this should receive careful consideration where speed in the completion of a plant is desired. Repairs on such a turbine take a long time and extra expense is incurred, since they generally necessitate dismantling the generator before the turbine parts can be reached.

The grouting in of large castings in a pit causes considerable deformation in these castings due to the local rise of temperature accompanying the setting of concrete. This entails in its turn the dressing down to fit of the big castings by hand, or the use of a disproportionate number of type metal joints. A double-runner unit of large size requires that the lower runner be set so low as to be, usually, under the tail-race water level, in order that the height of the draft on the upper runner shall not be too great. This makes it necessary to drop gates in the lower runner draft tube and pump down that draft tube to permit examination of the lower runner, a process which is usually an unduly long one. The rusting up or gumming up of gate-guide links and pins, where inside gate rigging is employed, as is usual in the case of double-runner concrete case vertical units, is a source of trouble.

The step bearing required for such a unit produces added complexity, resulting in higher cost of installation and higher cost of operation. The two or three floor levels usually incident to such vertical installations necessitate a second man and increase, for the chief operator, the difficulty of controlling the station.

Thrust Bearings

If the conditions are such that a vertical unit must be used, then I prefer roller bearings to pressure thrust bearings. In a 50,000-kw hydraulic power plant in the southern part of Pennsylvania both types were used and their operation compared. In the case of roller bearings the difficulty comes in obtaining proper roller plates quickly. The roller bearing on one of the units referred to has been running for over 18 months at a speed of 95 r.p.m. and carrying a load of 200,000 pounds without giving any trouble, although the plates in this bearing are not what would be called perfect plates. Such bearings can be easily and quickly installed and readily taken to pieces for examination. A few hours suffice for a complete dismantling and reassembling of such a bearing and this cannot be done with a pressure bearing, which in most cases has to have fitting done on it at site. The roller bearings can be run for some time without fresh oil, whereas with a pressure bearing the supply of pressure fluid must be continuous. Roller bearings will stand

harder usage. We have had a 1000-hp water-driven turbine-exciter motor jump up, due to a draft tube surge, and drop back on the bearing without injuring the bearing. The operating attendance required with roller bearings is less than that required with pressure bearings, and in the latter case a considerable auxiliary equipment in the form of pressure pumps, cooling coils, etc., is required.

Testing

Provision for making efficiency tests after the installation of hydraulic turbines is something that is often neglected in designing a plant, where in many cases, for practically no additional cost, it could be made. Accurate records of the efficiencies of generators of large capacity can be readily obtained by retardation tests and by measuring the electrical input to a generator driven as a motor by another generator. Efficiencies obtained by the two methods show a close agreement. A 7500-kw generator can be easily brought up to speed by driving from another generator, starting from rest with full field on both generators.

Mr. Arthur D. Pratt, New York City (submitted in writing): The Report states that the inherent defect in chain-grate stokers is the difference in thickness of the fuel bed which must be maintained, and adds that cold air in large quantities is continuously entering the furnace, impeded only by the ash at the back end of the grate. This statement is later qualified by reference to improvements recently made to overcome this difficulty by the use of an air or water-cooled back. This qualification I believe should be amplified somewhat. Our own practise has been to use a waterback. When a chain-grate stoker is properly operated, the bed of fuel is allowed to bank up against this back to a thickness corresponding to the thickness of the fire as a whole, and in this way a seal is formed between the end of the grate and the bridge wall, preventing cold air from passing through this space in large quantities. The waterback has another function, however, which is not usually appreciated. The fire on the rear portion of a chain grate is more irregular than that on the forward portion and there may be considerably more ash in one part of the rear of the fire than in another. The waterback, serving to check or slow up the movement of the rear portion of the fire, renders this portion more uniform,

closing up the holes and causing the passage of air to be more even and, to a certain extent, keeping the passage of air approximately the same through the whole fuel bed.

In connection with some other work I have been doing, I have recently gone quite thoroughly into the matter of the percentage of CO_2 to be expected in flue gas analyses with various types of stokers. From our records it would appear that under test conditions the percentage of CO_2 in the flue gases with chain-grate stokers would be somewhat higher than given in the paper. The percentage of CO_2 with the Murphy type of stoker will be slightly higher than with chain grates; with the Roney type slightly higher than with the Murphy, and with the Taylor type ordinarily slightly higher than with the Roney. It is to be remembered, however, that the percentage of CO_2 is not the flue-gas content affecting economical operation. This increase in the percentage of CO_2 for the Murphy, Roney and Taylor types over the chain-grate type, as stated, appears under test conditions. Under ordinary operating conditions, I believe that in most cases the percentage will be approximately the same as with chain-grate stokers intelligently handled. The explanation of this difference between test and operating conditions in the other types, and the more constant percentage of CO_2 to be found with chain-grate types under both conditions, is in the fact that chain-grate stokers are more nearly automatic in their action than the others, in that they require less working of the fires. The other types may operate with a higher percentage of CO_2 than chain-grate stokers for periods before it is necessary to clean the fires; but just before, during and after such cleaning periods the percentage of CO_2 will naturally be lower, and the effect on the average readings will be noticeable. These cleaning periods will, of course, vary in frequency, depending upon the coal and the rate of combustion. The chain-grate stoker requires no such cleaning interval and the percentage of CO_2 in the flue gases will be practically a constant quantity.

The Report speaks of a high percentage of CO_2 as indicating a higher efficiency. This statement I believe should also be qualified. It is not safe from a high CO_2 reading to assume without question an efficient combustion. Too often a high efficiency is taken for granted when such readings are secured, without carrying the analysis further to determine the remaining

content of the flue gases. As the percentage of CO_2 increases, there is a tendency toward the presence of CO. This naturally is not indicated by any CO_2 recorder which may be used and is very often difficult to detect with an Orsat apparatus. A small percentage of CO or even a trace, often more than offsets the good indications from a high CO_2 reading, and too much emphasis cannot be laid on the necessity of having a complete gas analysis giving accurately the amounts of CO. Solutions for its absorption, to be of value, must be fresh and capable of indicating the least trace of this gas.

The last paragraph of this portion of the Report refers to the greater adaptability of certain types of stokers to the higher grades of eastern coals. We have recently been doing a great deal of work in the handling of such coals on chain-grate stokers, and have been particularly successful both as regards capacity and smokelessness. In one instance we have run a boiler for six days at over 200 per cent of its rated capacity with practically no smoke and good efficiency. While this work may be considered as hardly past the experimental stage in establishing a limit, it is an indication of what may be accomplished.

Mr. Joseph Harrington, Chicago, Ill. (submitted in writing): A radical change in the status of mechanical stoking of eastern coals has occurred recently and the comments on mechanical stokers contained in the Report of the Prime Movers Committee do not adequately cover the ground nor touch the root of the matter.

The extent of the consumption of eastern coking coals and the marked changes in the efficiency of the chain grate for this service, render the subject one in which the Association will take the greatest interest. It is the desire of the writer to emphatically but briefly and clearly set forth the governing essentials in the matter of chain-grate stoking of eastern fuels, and to present a few pertinent comments on the underlying causes of its present efficiency.

Previous to a year ago, the chain grate was considered absolutely inapplicable to the coking coals of the eastern seaboard, and it was not attempted to place standard chain grates in any locality which involved the use of coking coals. The characteristics of this fuel and its action when subjected to heat make it impossible to uniformly ignite, coke and consume it unless it is

treated by auxiliary means to an extent which the standard chain grate does not and cannot provide. Increase in the draft only serves to accentuate the difficulties which are found to be present in such cases, causing holes to develop in the fuel, permitting a marked short-circuiting of the gases through these holes and seriously diluting the furnace gases. Even though the fuel can be successfully ignited, it has a tendency to draw together into masses or cakes, which eventually become solid masses of coke burning only on the surface. These masses of coke will then continue almost indefinitely as such and form either an undesirable accumulation at the bridge wall or pass into the ash pit unconsumed.

In addition to this unavoidable characteristic of the fuel, it forms a practically impervious layer near the front of the stoker and does not permit the passage of air under the influence of the furnace draft. It is, therefore, most difficult to ignite if undisturbed and almost equally difficult to burn out even if the ignition is successful and the draft able to furnish oxygen.

The eastern coals do not, as a rule, carry much ash, but the intensity of the fire which results from the combustion of clean coal is such that the ash it does contain readily melts in the furnace, and those types of stokers which disturb the general formation of the fuel bed inevitably produce clinkers by the fusing of the ash. There is but one proper method of burning bituminous coal and that is to allow it to remain quiet during the latter stages of combustion. Ash is naturally formed first at the grate surface where the oxygen supply is greatest and where the combustion is, therefore, earliest completed. An inversion of the fuel bed brings this ash layer to the surface and the incandescent carbon below, and a fluxing of the ash is inevitable. There is no getting away from the fact that this action is objectionable to an extreme degree, it being the primary cause of both the brick and metal deterioration in the furnace and stoker which inverts or mixes the fuel.

The eastern L type chain-grate stoker provides for two distinct zones in the combustion process; the first being for the distillation and ignition of the combustible volatiles, and second for the combustion of fixed carbon. The inclined coking plates, over which the fuel flows in its descent from the hopper to the chain-grate surface, are agitated to a sufficient extent so that the

fuel particles are in constant motion relative to one another, and the binding substance which exudes from the particles of coal is not permitted to "set" so as to cement such particles together. The length of the incline and the extent of its agitation are sufficient to provide for the complete distillation of the combustible volatiles, which precludes further caking of the fuel and produces a resultant fuel bed in the form of uniform coke of comparatively small size. The fragmentary and porous nature of such a fuel bed in turn permits the carrying of unusually thick fires and the nearly complete extraction of the oxygen from the entering air. It is quite possible to develop 16 or 17 per cent CO_2 in the furnace gases under conditions of commercial operation.

The reference to cold air in large quantities continually entering the furnaces does not take into consideration the airback which was developed particularly to meet the conditions imposed by the character of this fuel. The mechanism by which the waste of combustible in the ash pit or the unauthorized entrance of cold air to the furnace is prevented is an air-cooled surface of a nature similar to the surface of the chain grate itself, which is pivotally supported above the rear end of the grate and which approaches the grate surface to within about one inch. In fact, these airbacks are virtually an extension of the grate surface, the ventilating spaces being of similar nature and distribution, and cooled in the same manner. The air entering through the airback serves not only to keep it cool, but to assist in the combustion.

In its normal or vertical position, the airback completely closes the exit to the ash pit and prevents the discharge of any but a slight amount of cold ash. When, however, the refuse has accumulated to a sufficient extent in front of the airback on the grate surface, the mechanism can be rotated through about 90 degrees to a horizontal position, thereby opening the discharge orifice a sufficient amount to permit the ready and rapid discharge of accumulated refuse. It can be closed at any time at the discretion of the operator so as to retain such amount of refuse as he may desire.

The action of this device in its relation to the chain grate is essentially different from the dump plates of inclined stokers. The opening of the airback itself does not cause a discharge of

the refuse, but the travel of the chain grate is required to accomplish this end. It is quite apparent, therefore, that such discharge is under absolute control and can be stopped at any instant. This is in marked contrast to the dump plates of inclined stokers in that all of the material supported thereon, whether ash or combustible, is precipitated into the pit at the dropping of the dump plate. Under conditions of heavy load the aggregate of fuel dumped into the pit from these dump plates is serious in amount and great care must be exercised to prevent the abuse on the part of the fireman of this ability to clean his fires.

The ventilated surface of the airback is maintained by means of a circulation of cold air which enters the furnace in finely divided streams and impinges directly upon the accumulated fuel at the rear of the fire. Complete oxidation of all combustibles in the near vicinity of the airback is thus effected, and the air required for maintenance purposes is thus utilized to the best advantage in assisting combustion of the mixed fuel and ash on the grate surface.

The physical resistance of the airback to the travel of the fuel on the grate surface results in compacting the fuel to an extent that prevents its thinning out at this point. The tapering effect in its injurious aspects is eliminated and the coal is burned with a minimum amount of excess air and ash-pit loss.

The objection stated in the Report of the Committee regarding the unavoidable entrance of excess air at the rear of a chain grate is one which has been recognized and largely eliminated in even the western type of chain grates by a most careful attention to the baffling of the stoker and its setting, both between and under the chains and along the outside of the stoker frame. It is very possible to commercially obtain 12 per cent CO_2 in the western type of chain grate because of the completeness with which the baffling has been accomplished.

The compacting effect of a waterback in connection with the efficient baffling system of this stoker, combine to largely eliminate the conditions stated in the Report.

The Committee's reference to the smokelessness of mechanical stokers should be amplified by a consideration of the necessity of excessive brickwork in connection with the various types of stokers. A prime cause of smokeless combustion lies

in the uniformity of the fuel feed, and the greater this uniformity the less the necessity for excessive brickwork and combustion space. The obvious inference is that the stoker which handles the fuel with the least disturbance and with the greatest regularity, is the one in which brickwork maintenance is most likely to be at a minimum.

Natural draft has, until recently, been considered the only appropriate thing for chain-grate stokers, and a general idea is held as to the impossibility of applying this form of draft to this particular type of stoker. It is my desire to advise you that the coking coal chain grate lends itself most readily to the application of forced blast, and the advantages to be derived therefrom are equal to or greater than those which are generally accredited to the underfeed type of stoker. In the latter case, the fuel bed is, of necessity, of great thickness, and air pressures of several inches of water are required to force through the mass of fuel. Sudden decreases in combustion rates are, therefore, not as readily obtained as in chain-grate types of fuel beds because of the very fact of the large mass of incandescent coke contained therein. In the chain grate, the fuel is spread out over a large area of uniform thickness which is porous throughout its entire extent. The nature of such a fuel layer is to respond more quickly to the variations in furnace draft, and the fusing of metal parts or of the ash itself does not occur upon a sudden decrease in furnace draft. Moreover, the porosity of the fuel bed and its wide distribution make it possible to burn large quantities of coal with a minimum of air pressure, and rates as high as 65 pounds per square foot per hour have been developed. It makes no difference to the chain grate at what rating it is run, provided the minimum amount of air required to maintain the grate surface is provided. The rate of heat absorption through the exposed upper surfaces of the links is approximately a constant quantity, but the cooling effect of incoming air is in proportion to the amount of that air, so that the cooling effect of the grate surface can be said to be in direct proportion to the rate of combustion. It is obvious, therefore, that the harder the chain grate is forced the cooler the grate surface becomes. There is no apparent limit to the rate at which coal can be burned on such a surface. A marked difference in chain temperature is noted within the range of ordinary draft

variations. Nothing is gained by attempting to operate below a rating which corresponds to a balanced condition of heat absorption and radiation in the links of the chain, nor is there any efficiency gained in the furnace by a reduced rate of combustion. The efficiency of the oxidation process is absolutely independent of the rate of combustion, and in the properly designed chain grate the efficiency of the furnace is a constant quantity. This is in most marked contrast with the efficiency curves of other types of stokers.

The uniform efficiency of the chain grate reacts to a marked extent on the efficiency of the boiler and furnace combined, so that overall efficiencies with this apparatus are more nearly horizontal than in any other. What this means in the efficiency of the plant is difficult for those accustomed to old types of stokers to readily conceive. A further material advantage in the use of this stoker with variable loads exists in the ability to carry the lower ratings with natural draft and eliminate, during this period, the cost of operating the forced blast apparatus. The latter can be put into service on very short notice and be available during the peak load, at which time very high ratings can be developed if desired.

If a load variation of 300 per cent exists, it has heretofore been necessary to carry banked fires the greater part of the time because the peaked efficiency curve of the old-style units necessitated operating them at a rating corresponding to their maximum efficiency. It was found cheaper to stand all the losses of the banking period than to operate these units at points either much above or below their maximum efficiency. With the chain grate, however, it makes virtually no difference whether 20 pounds or 50 pounds of coal per square foot of grate surface per hour is to be consumed. The efficiency of a well-designed boiler does not vary in proportion to its rate of steaming, so that this combination results in a remarkably flat efficiency curve throughout the full range of commercial ratings. Add to this feature the ability to double-rate a furnace instantly and you have a combination which will revolutionize power-station business.

Mr. George J. Foran, New York City (submitted in writing): You have called attention to the chief points on condenser construction and operation which it is well the mem-

bers should understand. The subject of the baffling of condensers I took up some 11 years ago when I first assumed charge of the Condenser Department of the International Steam Pump Company, although not much was done for a year or two. The cooler was designed and patented about the same time and steps were also taken to separate the vacuum pumps into wet and dry units. The omission of certain tubes in the condenser to give the steam better access to the body of tubes and also to prevent the whirling of the tubes was tried out in one of the New York central stations, something like 7 or 8 years ago. With regard to velocity through the tubes referred to on page 500, I had no idea that a condenser would show 600 feet per second velocity through the tubes. This is a good point to call to the attention of the members, but the turbine men usually take a velocity of about 400 feet from the blades in the last stage, and we always desire to keep below that velocity through the condenser, gradually reducing until we have a very slow velocity for the non-condensed vapors through the cooler. I think your recommendations are good and merely submit my comments as a correction of the historical side of the development of the condenser, especially those condensers furnished by the company which I represent.

Mr. Klumpp: Your Committee is pleased to accept Mr. Denman's statements in reference to the tests on the large boilers at Detroit, especially his reference to the features which made possible the fine economy they obtained. At the same time it should be borne in mind that these tests were made under the direct supervision of one of the most capable testing engineers in the United States, and there is no doubt that he obtained the best possible results.

Referring to Mr. Stone's remarks, one might draw the inference that the first attempts to systematically measure the flow of gas in the pipe were made with the heating boilers at the Schenectady works of the General Electric Company. This is doubtless true when confined solely to the output of the steam boiler, but the United Gas Improvement Company of Philadelphia has for quite a number of years employed in its various plants a flow meter of somewhat different type, measuring the flow of a mixture of air and gas. We feel that Mr. Stone has exaggerated the deleterious effect on the boiler of a rapid and

wide fluctuation of load. While this may be true to a certain extent, we believe the great value of the steam-flow meter is in its aid to the economic operation of the boiler rather than in assisting to reduce structural strains due to change in load.

In reply to Mr. Yawger, your Committee thinks that Messrs. Lighthipe and Egan have answered him in the discussion, giving their experiences in firing with oil as a fuel, and have shown that when an oil furnace is correctly designed and operated the steam consumption for atomizing the oil is a very small proportion of the total steam generated. We think Mr. Yawger's experience in requiring a large percentage of steam was due to using oil as a fuel in a furnace combustion chamber which was not correctly designed for such use. However, as this fuel was probably used by him only in emergency conditions in a coal furnace, he did not—and probably could not—get as low steam economies in atomizing his oil as were obtained by the western operators, since their furnaces were designed for this purpose.

For Mr. Kemper's information your Committee wishes to state that oil engines are now being constructed in this country in single units of three cylinders, of about 250 horse-power, and this unit has been doubled with an electric generator hung between two engines, making a single six-cylinder unit of 500 horse-power. Oil engines of the Diesel type are in use driving electric generators in many small central electric stations, and when given good attention have operated with great reliability and exceedingly good efficiency. Of course, it is just as desirable to have reserve capacity as with other prime movers, for oil engines should be regularly overhauled and maintained in good order to secure the best efficiency.

Your Committee has no comments to make on the discussions submitted by Messrs. Pratt and Harrington. We feel that these contributions are the latest word from two very good authorities on chain-grate stokers. We desire, however, to call the attention of our members to the fact that while these gentlemen are very optimistic in reference to the use of high-grade eastern coal on their stokers, up to the present time very little has been done in a practical and successful way with the burning of such fuel on chain grates.

Your Committee is indebted to Messrs. Junkersfeld, Stone, DeWolf and some others for their very useful suggestions for

future work by this Committee. These will be referred to the new Committee for attention.

THE CHAIRMAN: The second number on our program for this morning is the report of the Committee on Electrical Apparatus, Mr. L. L. Elden, Boston, Chairman.

REPORT OF THE COMMITTEE ON ELECTRICAL APPARATUS

Your Committee on Electrical Apparatus, to which was assigned the investigation of all electrical apparatus within generating stations and substations, has continued the work begun last year, as far as it was possible in such a broad field. While the detailed instructions to the committee stipulated that this report should cover all electrical apparatus in generating stations and substations, beginning with the shaft of the prime-mover, it was believed advisable to include such information on the arrangement and character of land and buildings as would insure the best results in the economical and reliable housing of electrical apparatus.

An effort has been made to re-cite the state of the art, especially with regard to developments during the year, all of which is given in detail, together with numerous illustrations and examples, in the Appendix which forms a part of this report.

Your committee would call particular attention to the following developments and tendencies in connection with electrical apparatus:

(1) The demand for better economy, particularly in the operation of steam turbines, has, during the past two years, led to still higher speeds, especially on moderate and large-size units, and while very satisfactory results with such generators have been reported in several instances, experience is necessarily still quite limited. Special care should, therefore, be given to specifications for such high-speed generators to insure safe and reliable operation, and particularly in connection with reactance, temperature rise, ventilation and ruggedness of the generator. Because of developments during the past year, which will undoubtedly be followed by further improvements in design and materials employed, the committee makes no definite recommendations bearing on speed limitation.

(2) The great economic advantages of concentration in power production and power distribution in large areas (including perhaps dozens of cities, towns and villages) are becoming better known and much progress is being made in this direction. This results in a still more insistant demand for universal trans-

mission systems capable of supplying electric power for every possible purpose, thus opening up enormous possibilities for progressive central-station companies. The ultimate demand for power for railway purposes (now generally supplied by 25-cycle apparatus) will obviously be considerably less than the ultimate total electric power needed for all other purposes (now usually supplied from 60-cycle systems) in the same general territory. This condition makes an increasingly strong demand for 60-cycle rotary converters to supply power for railway purposes. For small and moderate-size units, 60-cycle rotaries can be made to render satisfactory service, and while further improvement is strongly urged in the design and construction of these, it is believed their use, or even the use of motor generators, is preferable in most cases to permitting the duplication of investment in 25-cycle transmission lines and converting apparatus. It is also believed that in many cases it will finally be found advisable for the central-station or power-transmission companies to have transmission lines and substations which will deliver energy in usable form for every purpose, including 600-volt direct-current to railway feeders, thus securing the benefit of the better diversity factor on transmission line and substation investment, as well as lower fixed charges and operating costs.

(3) The developments during the year also indicate a demand for simpler and more rugged switchboard equipment in substations, particularly small step-down transformer substations where intermittent attendance or at least less expert attendance is all that can be afforded. So-called iron-clad switch-gear has been used abroad to some extent and is also being favorably considered in this country, which apparatus your committee believes deserves careful consideration for such particular conditions.

The following subjects have been investigated and treated in considerable detail. In some instances, attention is called to faults which have been developed in existing apparatus; in other instances, warning has been given of possible trouble, and in others further research or experimentation is suggested:

1. Character and arrangement of land and buildings for electrical apparatus.
2. Foundations and supports for electrical apparatus.
3. Turbo-generators and reactances.
4. Induction generators.

5. Exciters.
6. Station transformers and auto-transformers.
7. Compartment oil-switches and disconnective switches.
8. Switch and bus compartments.
9. Current and potential transformers.
10. Relays and automatic protective devices.
11. Rotary converters.
12. Motor generators and frequency changers.
13. Substation equipment.
14. Rectifiers.
15. Feeder regulators.
16. Lightning-arresters and dischargers.
17. High-tension direct-current transmission.
18. Arcing ground suppressor.
19. High-potential cable-testing set.
20. Electro mechanical signals.
21. Cable and wire for connecting electrical apparatus.
22. Principal existing standards of instrument and switchboard equipment for different conditions.

In submitting this report the committee wishes to thank all upon whom requests were made for information, and to assure them of its appreciation of the assistance thus received.

Respectfully submitted,

Committee { L. L. Elden, *Chairman*
Harry M. Hope
P. Junkersfeld
G. L. Knight
D. Fred Schick

APPENDIX

Buildings and Grounds

Attention is called to the recent development of a type of building for generating and substation in localities where the fire hazard from without has to be carefully considered, in which a minimum of openings are provided in order to reduce the hazard from fire or water. One company has found it desirable to eliminate all openings except those for bringing in apparatus, with a monitor on the roof for light and ventilation. Local conditions must govern the design of buildings, both as regards the fire hazard and architectural treatment in general, but consideration must be given to providing a proper amount and source of light and ventilation. In general, it is highly desirable to use light colors for finish wherever possible on walls and structures, in order to promote safety and cleanliness, and to maintain a high morale on the part of the operators.

The prevailing tendency toward the ornamentation of grounds surrounding generating and substations is highly commended as a step in the direction of welfare work in improving the conditions under which the operators perform their duties.

Recent good examples of the several types and designs of station buildings and ornamentation of grounds surrounding stations are shown in the following illustrations, showing stations of the Philadelphia Electric Company, San Francisco Gas and Electric Company, and the Edison Electric Illuminating Company of Boston.

Foundations for Apparatus

It is the usual practise to provide brick or concrete foundations in generating or substations for such apparatus as rotary converters, motor generators or other similar rotating apparatus. Several companies are employing structural steel for such supports with marked success, there being no trouble experienced from vibration. This form of construction lends itself to obtaining better clearances and improved ventilation, and at the same time does not increase the cost of construction. It is suggested that structural supports be protected by concrete or similar coverings to prevent live conductors coming in contact with grounded structural members where such possibilities exist.

FIG. 1—SUBSTATION OF PHILADELPHIA ELECTRIC COMPANY, IN RESIDENTIAL DISTRICT, NOT EXPOSED TO FIRE HAZARD

Fig. 2—Substation of San Francisco Gas and Electric Company, Designed to Include Ornamental Features as Well as to Meet Fire-Hazard Conditions

Fig. 3—Substation of The Edison Electric Illuminating Company of Boston, Located in Residential District, Not Exposed to Fire Hazard

Turbo-Generators and Reactances

Since the presentation of the 1911 report of this committee, 20,000-kw turbo-generators have been put in operation in the Waterside Station of the New York Edison Company. Several other similar installations are in progress in other localities in this country and in addition a 25,000-kw turbo-generator has been purchased for installation in a station of one of our large companies.

The committee again calls attention to the necessity of providing some method of restricting the large volumes of current

Fig. 4—Interior of Windowless Substation Located in District where Fire Hazard is Serious

which large turbo-generators are able to deliver under short-circuit conditions. The solution offered is the insertion of current-limiting reactance in the external circuit of such machines, or so designing the generator and its attending equipment that a reasonably high internal reactance will result.

A number of successful installations of external reactance coils were reported during the past year, notably that of the Commonwealth Edison Company, which has installed reactances similar to those described in the previous report, in the circuits of all turbo-generators in service.

In other cases where auto-transformers or step-up transformers are included as part of the generator unit, such installa-

FIG. 5—STATION OF THE EDISON ELECTRIC ILLUMINATING COMPANY OF BOSTON, SHOWING ATTRACTIVE ARRANGEMENT OF GROUNDS

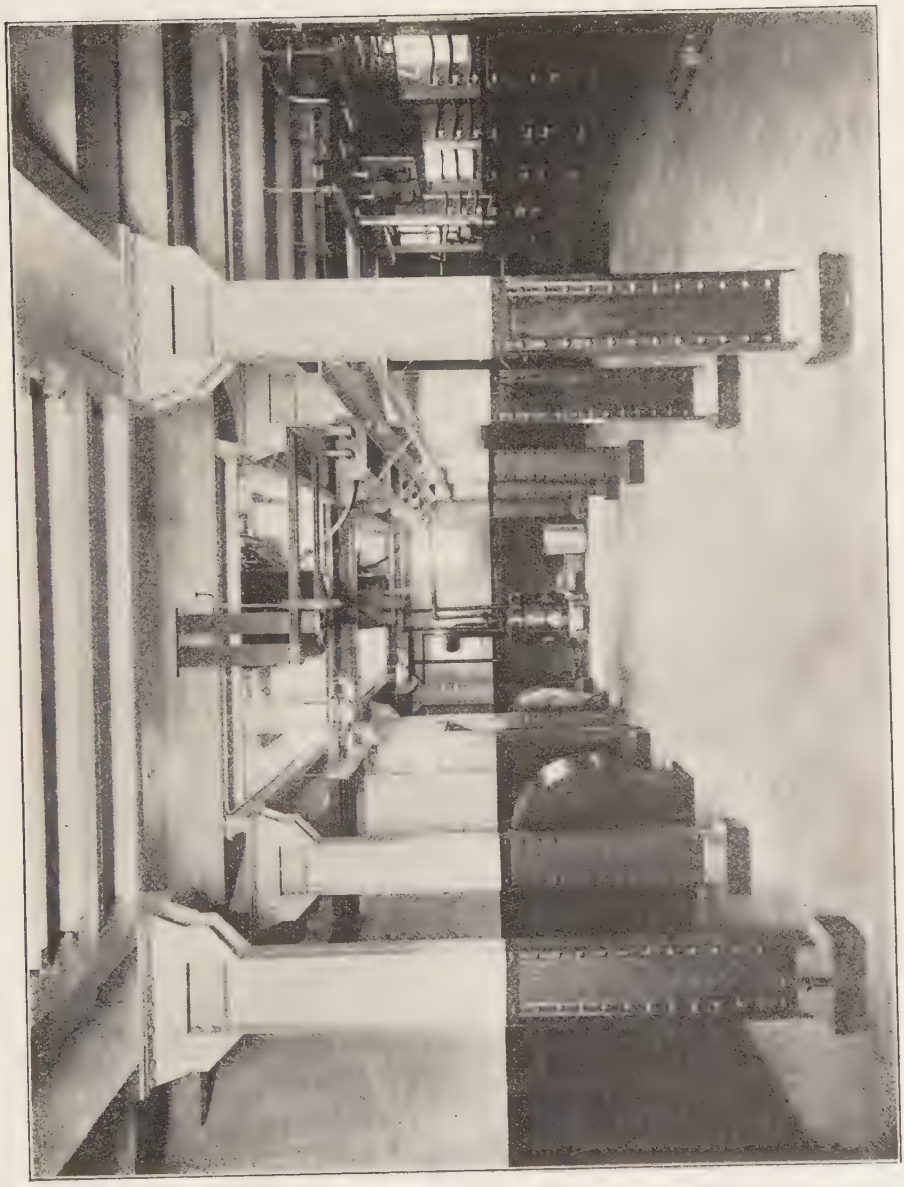


FIG. 6—STRUCTURAL STEEL FOUNDATION FOR 2000-KILOWATT ROTARY CONVERTER

tions are so designed that the combined reactance of generator and transformers is sufficient to limit short-circuit currents to safe amounts.

Induction Generators

The excellent operating features of this type of generator have received little recognition from the electrical supply companies. Several prominent companies, notably the Interborough Company of New York, have installed generators of this character and operated them with great success; in fact, in certain locations no other form of alternating-current generator would have satisfactorily performed the required duties.

The principles governing the operation of induction generators find a parallel in the commercial induction motor. Ordinarily operating with a certain amount of slip under all loads the induction motor, when driven above synchronous speed by a prime mover, becomes a generator returning power to the main system in proportion to its capacity and excess speed above the normal synchronous speed of the system.

In contrast with the standard synchronous generator, which requires direct current for excitation, the induction generator requires alternating current for excitation. The amount of excitation required may be as little as one-half that required by a synchronous generator of equivalent capacity, due principally to the smaller air-gap inherent in the design of the induction generator.

This excitation current is drawn from the system, being derived by over-exciting synchronous apparatus such as converters, synchronous motors and condensers. In cases where there is present a cable system of considerable electrostatic capacity, this capacity is of material value in furnishing a portion of the leading current necessary for the excitation of induction generators, thereby reducing the wattless current which would necessarily be drawn from the synchronous apparatus if there was no cable present in the system.

This absence of exciters and other auxiliary regulating devices makes the equipment of an induction generator particularly attractive. Inasmuch as the induction generator is not capable of furnishing power to a low factor load, the generator becomes particularly valuable in limiting the amount of current

delivered to a short circuit. Where operated in conjunction with other synchronous generators, the induction generator exercises a favorable influence in preventing any distortions in wave form when momentary disturbances, such as short-circuits, ground-currents and overloads, tend to materially distort the wave form of the synchronous generators.

The induction generator when designed for the exact duties it has to perform, with particular reference to speed and frequency, shows excellent efficiencies, in fact somewhat greater efficiency than synchronous generators of the same capacities.

The ordinary practise in operating induction generators is to throw them directly on the system, through suitable reactance coils limiting the rush of current. No synchronizing is necessary to connect an induction generator to a system, the only precaution necessary being to run the generator at approximately the speed at which it should run when in service. Aside from its high efficiency, the induction generator offers advantages in several ways, viz.:

Reduction of short-circuit currents.

Elimination of resonance.

Reduced excitation compared with synchronous generators.

Rugged mechanical characteristics.

Elimination of exciters and reduction of switching equipment.

Simplicity of load control by use of variable reactance, or by variation of speed of prime mover.

The only unfavorable characteristic seems to be its inability to supply energy to a system of low power-factor.

To those companies whose systems have reached capacities where short-circuit currents have high values, the induction generator is particularly valuable.

Such an authority as Dr. Steinmetz may be quoted as advovating the use of the induction generator, and it has therefore been thought wise to bring the matter to the attention of the Convention.

Exciters

The excitation system is conceded to be the point at which the maximum of reliability is desired; therefore some companies maintain a storage battery in reserve, floating on the exciter-bus

at all times, with steam-driven exciters in reserve as well. Three general schemes for the operation of exciters are in vogue; steam-driven exciters, motor-driven exciters and exciters driven by belt directly from the alternating-current generator shaft or otherwise.

The first and last methods being positive, little need be said of the possibilities for the failure of such exciters. Motor-driven exciters are in general use throughout the country and may be considered as standard apparatus. Induction motors are to be preferred with systems where no storage battery is maintained floating on the exciter system as an auxiliary reserve. Synchronous motors may properly be used in connection with exciters where storage batteries are held in reserve, but such exciters should preferably be shunt-wound, or at least arranged for flat compounding and equipped with circuit-breakers on both alternating-current and direct-current units. It is extremely important that reverse-current relays and circuit-breakers be used with all compound-wound exciters to prevent reversal in case of failure of alternating-current supply. Such circuit-breakers should also be connected for operation from a speed-limiting device on the exciter shaft.

Station Transformers

The use of auto-transformers to raise the pressure of low potential generators of large capacities has opened a comparatively new field for transforming apparatus. Such transformers are recommended for that purpose on account of lower first cost, increased efficiency and reduced capacity as compared with step-up transformers for the same purpose. It should be understood that this recommendation applies only to installations where it is impossible to obtain satisfactorily designed generating units of the capacity and pressure required.

When station-transformers of the air-cooled type are used, care should be taken to insure a sufficient supply of clean air tempered where necessary to prevent condensation on the transformer coils. Manufacturers are apt to be conservative in their recommendations on the quantities of air required for properly cooling air cooled transformers, and therefore blowing systems of this character should be liberally designed in excess of manufacturers' specifications, both as to size of blower and supply of air.

In view of the importance of positively maintaining the forced air circulation in air-cooled transformers, it is advisable to provide all transformers with mechanical indicators arranged with an audible alarm to notify operators of failure of air supply. An excellent device of this character is shown in the accompanying cut.

Fig. 7—Signalling Device for Air-Cooled Transformers

Manufacturers have not thus far, within the knowledge of the committee, furnished an acceptable damper on air-blast transformers, which will effectually cut off the air from a single transformer in a group of air-cooled transformers in case of fire in a single transformer unit.

Rigid clauses should be inserted in specifications for air-cooled transformers insisting on proper dampers not only for the purposes above mentioned, but where groups of single-phase transformers are used it is often desirable and necessary to cut out one transformer in case of trouble, leaving the remainder of the group in service, in which case excess air is required for the remaining transformers.

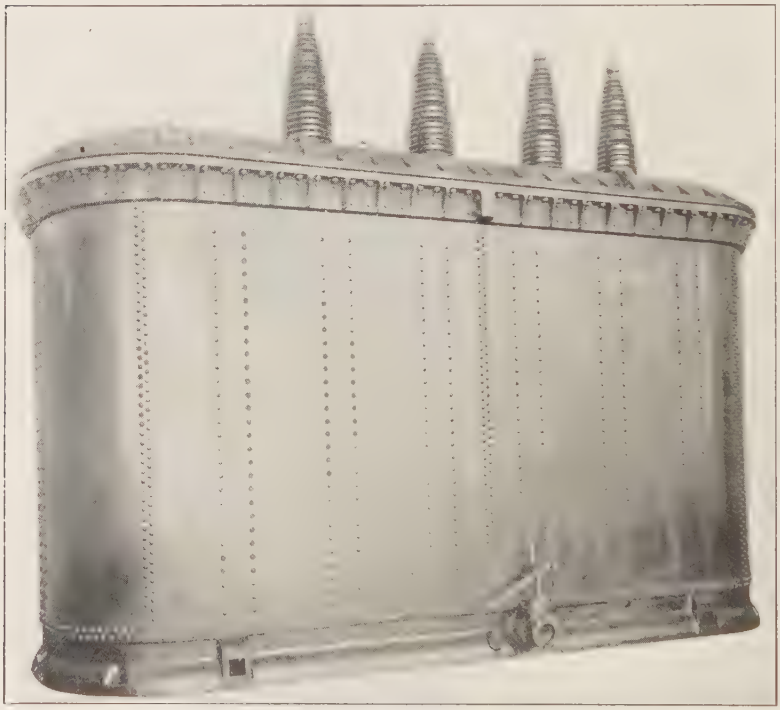


Fig. 8—14,000-Kva, 97,000-6600-Volt, Oil and Water-Cooled Transformer

One company has found it desirable and convenient to replace with glass doors, the cast-iron doors usually placed in the sides of the bases of air-blast transformers to give access to low-tension terminals. This plan permits of ready inspection of the connections in the bases of transformers, without entering the air chamber, and simplifies in a measure the problem of keeping all such spaces clean.

Transformers have been destroyed by fires resulting from failure of cable joints in the bases of transformers. It is recom-

mended that all cable connections made by soldering cables into copper lugs should also be pinned through both cable and lug after soldering, to prevent the possibility of such joints opening from heating of the conductor under load.

Where oil-cooled transformers (including rectifiers) are used, it is highly essential to make provision for isolating transformer units to prevent spread of fire, and, in addition, means should be provided for quickly drawing off the oil from each unit.

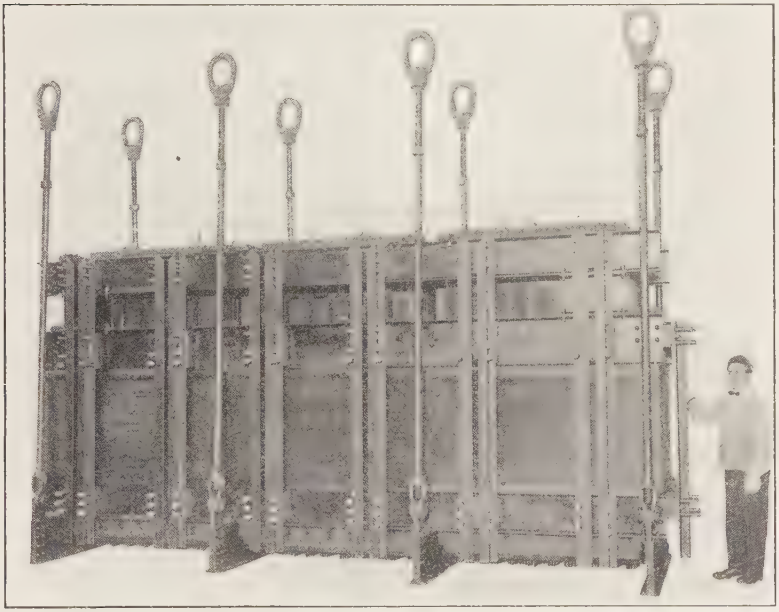


Fig. 9—14,000-Kva, 97,000-6600-Volt, Oil and Water-Cooled Transformer

It has been clearly demonstrated that transformer oil will not burn in the transformer cases like a torch, nor will it burn at all unless raised above its flash-point by extreme heat or, what is more likely to happen, when spread out in a thin film over the floor where it can readily mingle with dust.

It is therefore most important to prevent oil spreading on the floors of stations in case of leakage or overflow of transformer cases, and individual transformer units should be so isolated as to prevent spread of fire to other apparatus in the station.

Special care should be taken to eliminate or guard all pet-

cocks or other small fixtures on transformer or rectifier cases, which may be knocked off and cause leakage of oil.

One scheme suggested for handling oil in emergencies provides pits around each transformer unit. These pits are suitably arranged with pipe connections to an auxiliary underground oil

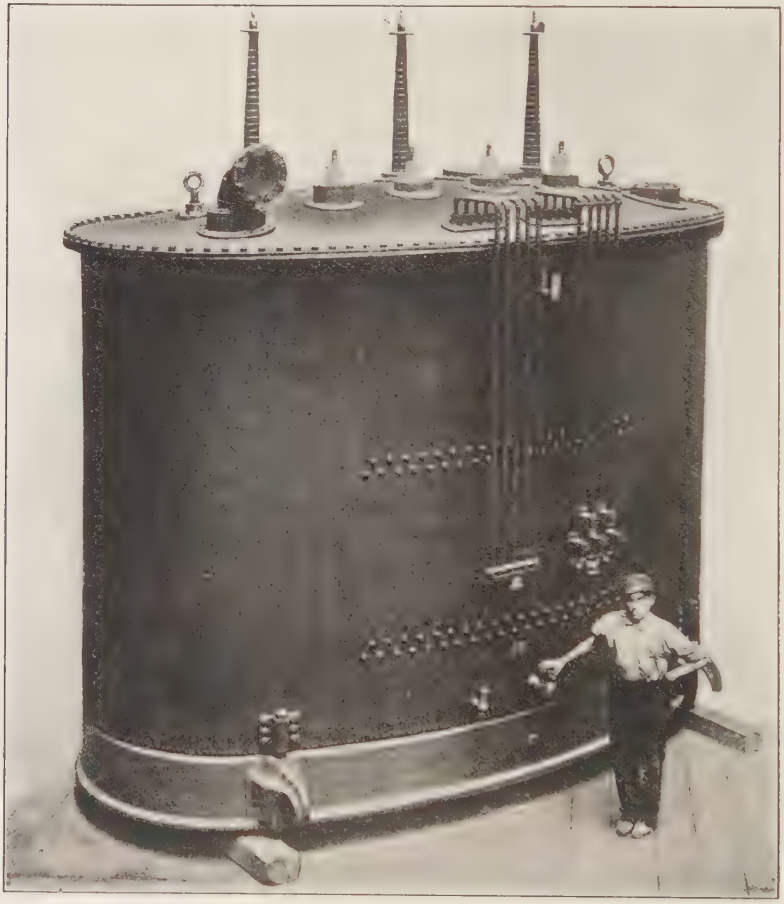


Fig. 10—10,000-Kva, 60,000-13,200-Volt, Oil and Water-Cooled Transformer

tank, or else to the sewer. All openings in such pipes should be fitted with fine mesh screens to prevent passage of flame to tank or sewer. If auxiliary tank is used, compressed air may be used to force oil back into transformer tanks.

FIG. 11—2000-KVA, 100,000-13,200-VOLT OIL-COOLED TRANSFORMER

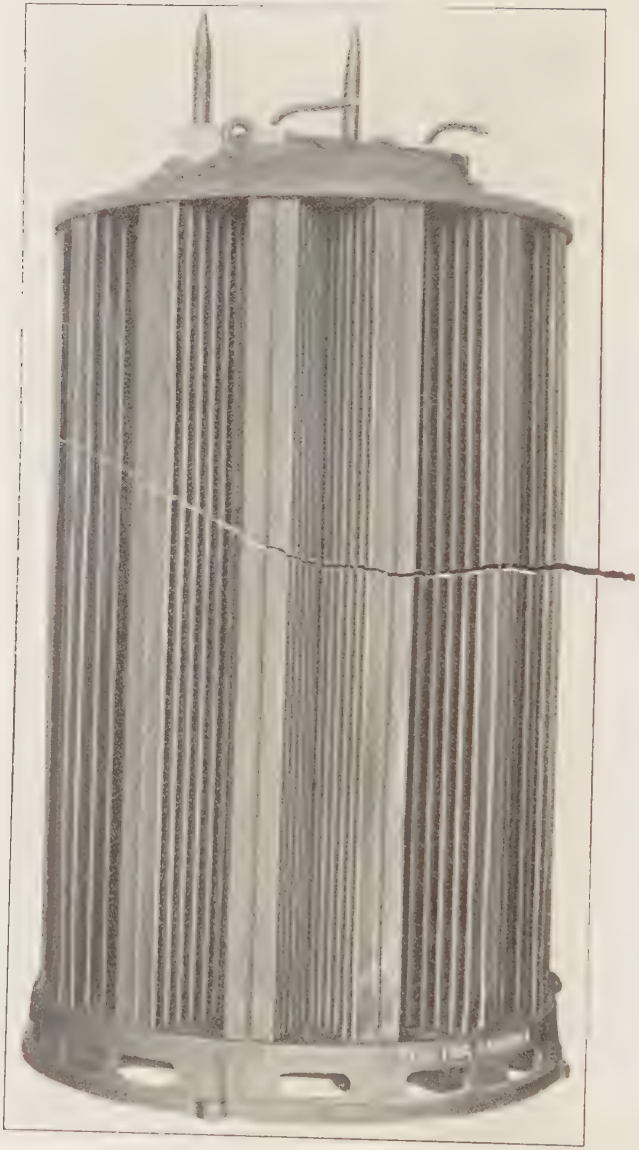


Fig. 14.—New Type Case for Oil-Cooled Transformers

Fig. 13—High-Voltage, Weatherproof, Out-door Type, Oil-Cooled Transformer

The importance of keeping transformer oil in good condition calls attention to a motor-driven oil-filtering equipment recently placed on the market. This apparatus may be employed to renew or cleanse the oil in a transformer case without taking the transformer out of service, and the systematic use of such apparatus is fully recommended.

With the large concentration of power in some systems the need for rigid construction and effective means to limit excessive

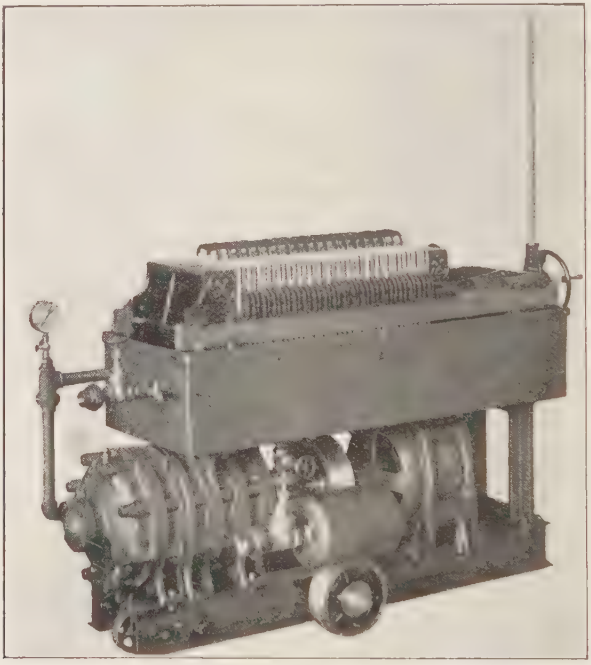


Fig. 14—Motor-Driven Oil Dryer and Purifier. Capacity 30 Gallons per Minute

short-circuit currents in station transformers is becoming more and more necessary.

Recent designs of transformers are noted to include high reactance between high and low tension windings as a means to limit mechanical stresses in the windings when subjected to heavy short-circuits. The introduction of high reactance necessarily effects the inherent regulation of the transformer, but the pro-

tection afforded is considered of greater importance than the increase in the regulation factor.

The amount of reactance which it is desirable to introduce into transformers will vary according to design and overload

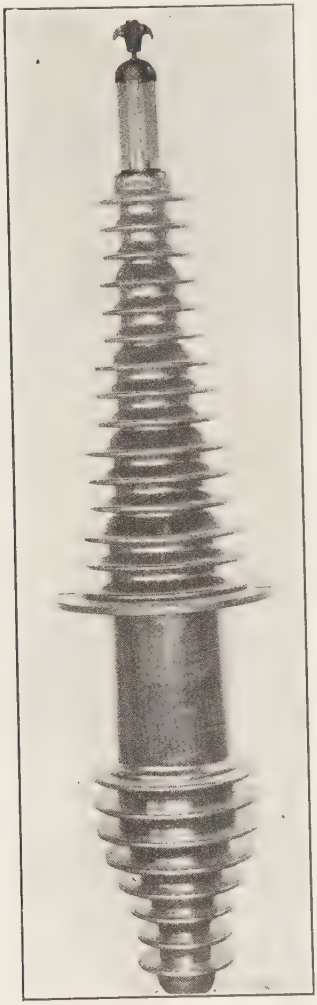


Fig. 15—Recent Form of Oil-Filled, High-Tension Leads for Transformers

capacity of each transformer, as well as the conditions under which they are to operate. In the past the reactance in standard

power transformers has varied from one to six per cent, but it is now noted to be the general practise of manufacturers to include from four to eight per cent reactance in all large power transformers, according to their design.

In general, manufacturers do not report any radical improvements in the mechanical construction and design of large transformers. Reduction in losses through further improvements in steel, changes in design and construction of tanks, substitution of rivets for bolts to bind laminations together, replacing of wooden terminal supports by porcelain, and material advances in both quality and heat-resisting characteristics of insulation are the principal improvements noted during the past year. Thermometers on transformer tanks and sight-feed indicating devices for water circulation are noted among other refinements in details of transformer construction.

High-voltage transformers adapted for installation out of doors have been developed and are now available for voltages up to 88,000 volts. This has been made possible by the design of suitable terminal bushings for the protection of transformer leads when exposed to the weather.

High-voltage transformers of both oil and water-cooled types, continue to be manufactured in ever-increasing capacities, but still retain the same general mechanical characteristics. Considerable progress has been made in the design of terminals for such transformers and two general types are noted to be in use; viz., the condenser and the oil-filled type.

Manufacturers of transformers continue to be handicapped by the absence of any standardization in voltage and frequency, and every effort should be made for uniformity in these respects for economic reasons.

Cuts of typical transformers are included on the following pages.

Oil-Switches

A number of developments in oil-switches have resulted from the very complete tests made in Chicago during the spring of 1911, the results of which were given in papers presented by Messrs. Schuchardt and Schweitzer, of the Commonwealth Edison Company, and Mr. Merriam, of the General Electric Company, at the convention of the American Institute of Electrical Engineers in 1911.

The study of the action of the oil and gases in the oil-switch tanks led to the modification of the baffles inside the tanks and the strengthening of the insulators and supports, as well as other minor changes, which it is claimed enable these switches to rupture much greater energy than ever before.

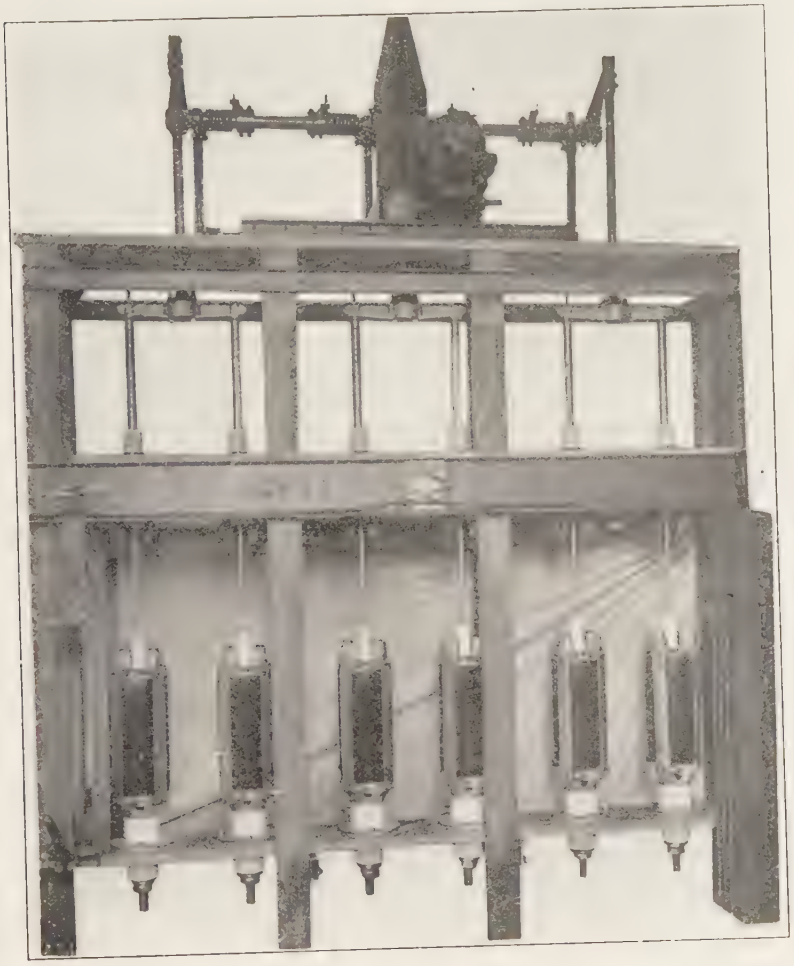


Fig. 16—2000-Ampere, 15,000-Volt H-Switch

The ever-increasing capacity of the large generating systems, as well as the introduction of large turbo-generator units of 15,000 to 20,000 kw, automatically produced a demand for

heavier duty switches. Based upon the experience in the Chicago tests one manufacturer has brought forward an extremely heavy duty switch of the H type for use on generators of large capacities at moderate voltages. Illustrations of this switch indicate its extremely rugged construction, and reports from such

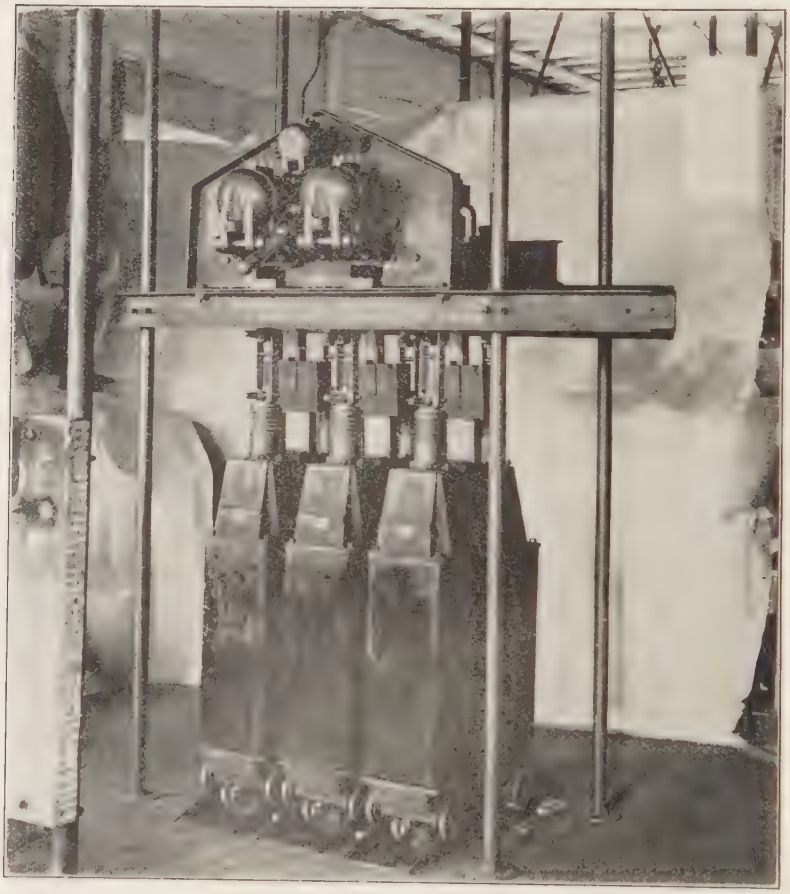


Fig. 17—1000-Ampere, 15,000-Volt, Solenoid-Operated Switch

of these switches as are in service show satisfactory operation.

Recently another manufacturer has undertaken an extensive series of tests on oil-switches at Niagara Falls, the results of which would undoubtedly be of great interest to the profession if made public.

Still another manufacturer has brought forward a new type of oil-switch for heavy duty, adapted to break large amounts of energy, and for which much is claimed, but so far as the committee is informed no definite results have been obtained in actual tests of the switch on large systems.

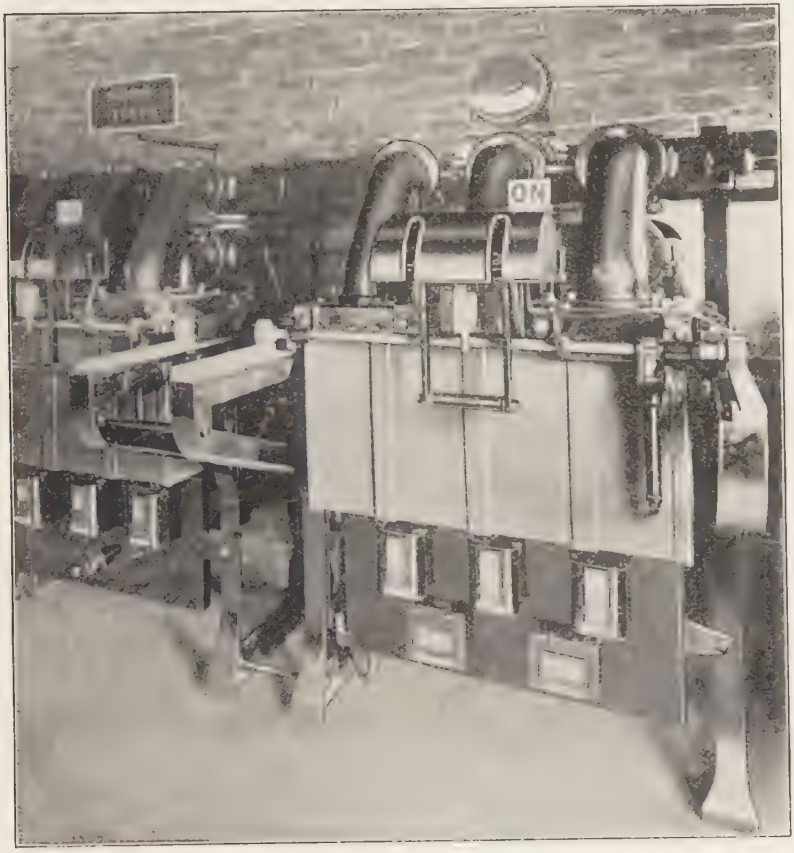


Fig. 18—20,000-Volt, 300-Ampere, Ironclad Switch Gear

At least two member companies have purchased sample switches of what is known as the Reyrolle Iron-Clad Switch-Gear, a type of switch-gear now in general use in England. These have been purchased for experimental purposes to determine what advantages, if any, that form of construction affords over those now in use in this country. This type of switch-

gear, from its enclosed construction, apparently affords excellent protection to station operators, and is of interest from that point of view if from no other.

Switches for high-tension and extra-high-tension systems

Fig. 19—110,000-Volt Oil-Switch (Single-Pole Unit)

have reached a high state of development. Recent designs suitable for use on 110,000 to 140,000-volt systems present a formidable appearance, as regards external dimensions and construction, although extremely simple mechanically.

Observation of new construction by high-tension transmission companies shows an increasing tendency toward the use of out-door switching stations. Notable installations of this character are those of the Dominion Power and Transmission Company, Southern Power Company, Hydro-Electric Power Commission of Ontario and Telluride Power Company.

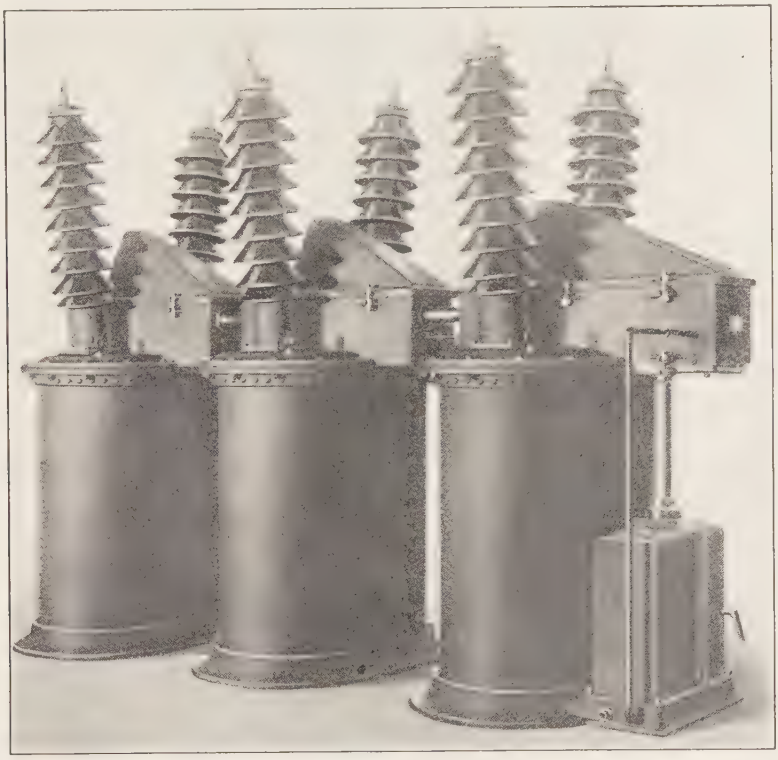


Fig. 20—100,000-Volt, Out-door Type, Oil Circuit-Breaker

Switches of both the air and oil-break types are used in these installations, operating at pressures varying from 44,000 to 88,000 volts, and such reports as are available indicate successful operation under all conditions of weather and through temperature variations from 100 degrees above, to 16 degrees F. below zero. The committee suggests that particular attention be given to this form of switching installation during the coming

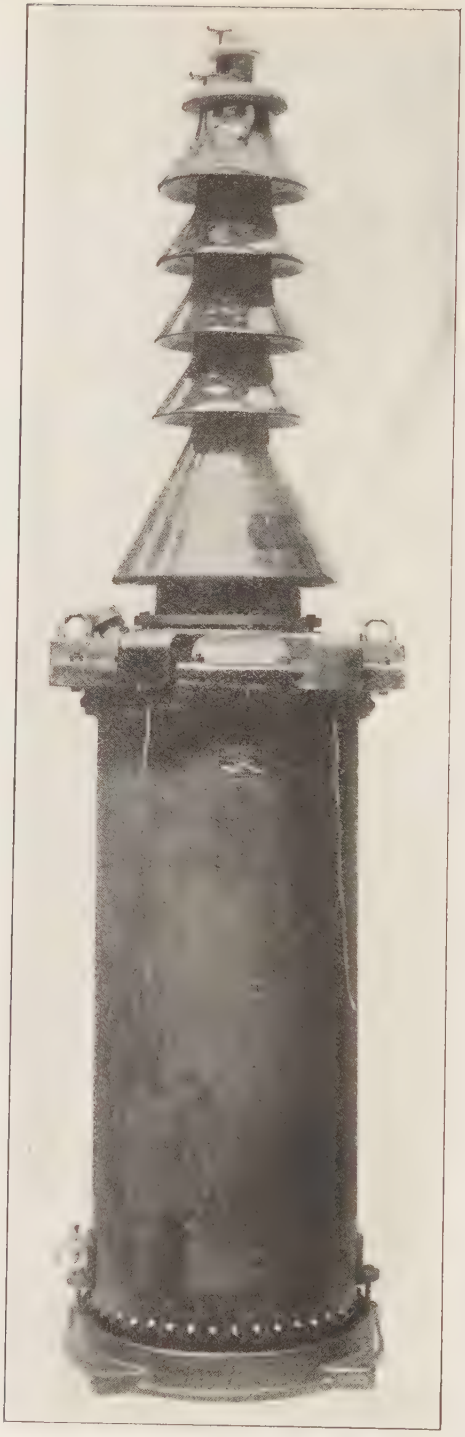


Fig. 21.—88,000 Volt, Out-door Type, Series Transformer for Operating Oil Circuit-Breaker

year, to determine, if possible, the relative investment required for such stations as compared with those with which we are more familiar.

Disconnective Switches

The committee strongly recommends that those member companies who have not given careful consideration to their methods of installing disconnective switches, should inspect their installation of this type of switch and make such changes in construction as may be necessary to eliminate all danger due to the action of magnetic fields around these switches at time of short-circuit in generators or feeders with which they may be connected, as emphasized by recent accidents of this character.

In the usual designs of disconnects there is either a 90 or 180-degree turn of the conductor from the stud of the disconnect to the bus, and a very strong field is here developed at times of short-circuit which may throw open the switch in case of absence of locks; or, as happened in one case where the switches were locked, may tear the entire switch with its insulators away from its supports. The time lag of an oil-switch is all that is necessary to permit disruptive action from this cause. The lead from the bus to the top of the disconnective switch should be as straight as possible, and the disconnect so placed that it is part of a considerable length of straight conductor.

The utmost precaution should be taken by operators in opening disconnects in order to prevent the possibility of opening such switches while carrying current. Several companies go to the extent of giving orders to two men whenever disconnects are to be opened, one man checking the other before the switches are actually operated.

Switch and Bus Compartments

The larger installations of bus compartments made during the past year for systems of moderate pressure, still show the former divergence in practise with reference to conductor insulation. One notable installation has been designed for unprotected bare bus-bars with the conductors separated by concrete barriers, while another is built with insulated bus-bars strongly supported and separated by barriers and covered with asbestos board.

These two types of construction represent the extremes; the one chosen with the idea that insulation over conductors gives a

false sense of security, and the other that the insulation supplies an added factor of safety. The committee believes that in such cases as the bare conductor method of construction is used, suitable guards should be provided to prevent accidental contact with live conductors which may be within easy reach of the operators.

A proposed form of construction for bus compartments, designed to reduce the cost of bus structures as usually made, is shown in an accompanying illustration. It is proposed to use a hollow tile of suitable dimensions so designed that it affords all the necessary facilities for bus-bar supports and wiring, and at the same time will be cheaper and easier to install than concrete

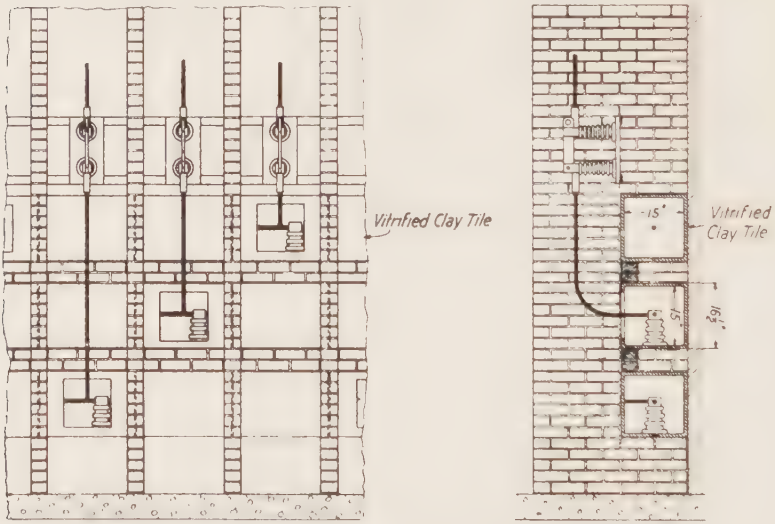


Fig. 22—Proposed Vitrified Clay Tile for Bus Compartments

or similar materials which are now used for this purpose. It will be of interest to note the further development of this form of construction.

Switch compartments should be so designed as to eliminate all possibility of spread of trouble resulting from failure of switches to open the circuit, or from the explosive action of switch tanks.

One company has modified the construction of the doors ordinarily used in front of switch compartments, by arranging the fastenings so that the whole door may not blow out in the event of an explosion in the switch. Panels in the doors are adjusted

to open easily when necessary, but so arranged that there is no path for the explosive gases between adjacent phases of the switch.

Current Transformers

The recommendations of the committee regarding single-turn current transformers, as included in its 1911 report, are repeated. One manufacturer has developed a full line of single-turn transformers, and the use of transformers of either this or any other indestructible type will, in the opinion of the committee, be a great step toward eliminating the dangers arising from the failure of current transformers to which attention was called last year.

Great care, however, must be taken in selecting the size and type of transformer to be used in specific cases, but as complete data is now available showing the ampere capacity of the primary for each size of transformer, the volt-amperes of secondary current which the transformer will deliver and the load taken by different classes of switchboard instruments, trip coils, etc., the designer of generating and substations is able to select intelligently the type of transformer best suited to his needs.

Where a transformer of low ratio is required, especially in generating stations, the single-turn primary type should be used next to the bus for tripping oil-switches, and because this type is necessarily inaccurate for energy measuring instruments, if such instruments are required, a second transformer of the wound primary type should be used in series with the first to furnish the secondary current for the energy measuring instruments. In selecting transformers the ratio of rated capacity to normal load must be given careful consideration, in order to be sure of adequate tripping current where the ratio is high in relation to the normal load.

Some years ago one of the large manufacturing companies put the name-plates on their current transformers directly on the outside of the winding, attaching the brass plates by means of screws to a wooden block embedded in the winding. Recently a man was killed by simply rubbing the dust off one of these name-plates in order to read it. On investigation it was found that a long screw, which had been used in one corner of the name-plate, had penetrated the primary insulation, the transformer having

been in that condition for years waiting for a victim. The manufacturing company in question changed its method of installing this plate some time ago, and now mounts it on the legs of the transformers, but as many of the member companies doubtless have transformers with the name-plate mounted in the old way, their urgent attention is called to this danger.

Potential Transformers

The committee repeats its warning as to the location of potential transformers where bare terminals are exposed; first to eliminate all possibility of danger to life, and secondly to prevent, so far as possible, the spread of fire through short-circuits resulting from exposure of live terminals to large arcs developed by fuse failures when a transformer proves defective. It is particularly desirable to mount all transformer fuses in separate compartments distinct from the transformer which they protect, this form of construction having been shown to be an excellent feature to insure freedom from trouble developed by fuse failures.

A number of new developments have resulted from the desire for better potential transformers, especially as regards the fusible protective devices furnished with the transformers. Efforts have been made to develop a fuse which would not only safely interrupt the current in case of short-circuit in the transformer, but would operate in case of overload as well. As the usual potential transformer has a capacity of 200 watts, the normal load is .03 of an ampere at 6600 volts, or less in case of higher voltages. This means that the fuse must be of extremely low carrying capacity, and fusible wire to meet these requirements has proven hard to find.

Reports of further tests of the chemical fuses referred to in the 1911 report show uniformly satisfactory results under severe conditions, which, added to the extended experience of a member company with this type of fuse, indicates their value as a reliable fusible device for high-potential circuits.

One company has developed a cartridge fuse mentioned in the 1911 report, and this has undergone severe test during the past year. So far as the committee knows, this fuse has proven uniformly successful at 13,000 volts and below.

Another company has developed a fuse contained in a porcelain tube, which eliminates the bare contacts on the transformer. The porcelain fuse-retainer has a handle integral with it for removing the fuse, so that the operator cannot come in contact with the bare copper, even if one end of the fuse be inserted with the other exposed during the process. The tube contains a fuse-wire embedded in a chalky substance, which effectually kills the arc, the tube being filled at the ends with insulating material.

A number of accidents have been reported as due to rats or cats coming in contact with live potential transformer terminals, from which it will be seen that the most desirable form of construction for such transformers would be one that did not include any exposed high potential terminals.

Extreme care should be taken to connect potential transformers to the system at points where they will be afforded the protection of automatic oil-switches. Numerous cases are on record where transformer failures have caused total interruptions of service due to their being connected directly to the bus, without other protective devices than their own fuses, which proved inadequate.

Relays

In the 1911 Report, attention was called to the need for relays which would give selective action in the case of radial feeders, and manufacturers have given this matter a great deal of attention during the past year. Relays from at least three companies have been under test and all seem to give promise of a solution of this problem. None of the relays, however, have yet been subjected to sufficiently exhaustive tests in actual use on systems to enable the committee to make definite recommendations.

Special attention is called to the merits of the Merz-Price system of relay protection, using differential relays with pilot wires, for the protection of ring systems of feeders. This system is made operative by installing current transformers at each end of a transmission cable, the secondaries of which are connected in opposition through the pilot wires. Relays, suitably arranged to be operated by currents developed in the pilot wires by unbalancing of current in the main conductors, control the operation of the main oil-switches to disconnect a faulty section of cable without disturbing the remainder of the system. The

principal merits of this system are the facilities it affords for continuous operation, and the more economical use of line capacities resulting from interconnection.

Compound wound generators in substations should in all cases be provided with reverse-current relays to operate circuit-breakers to disconnect such generators from the direct-current bus, upon the failure of the alternating-current supply, in order to prevent reversal.

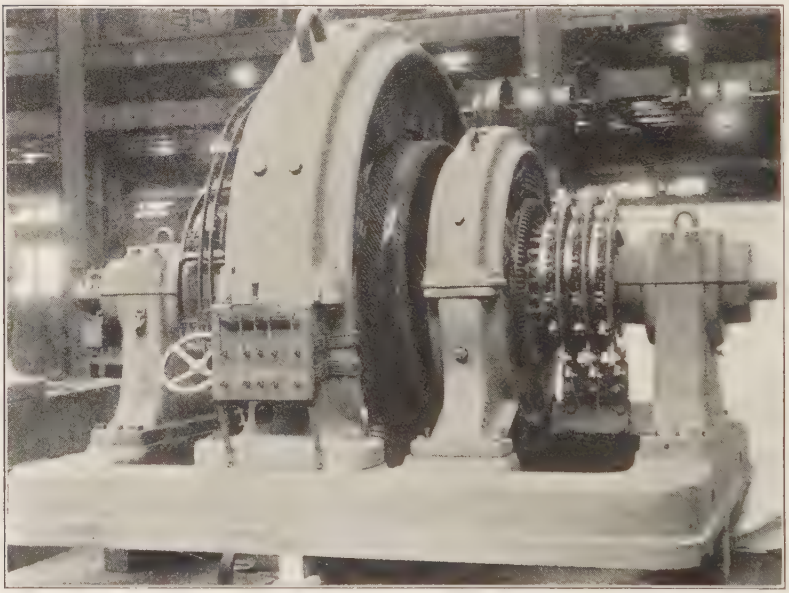


Fig. 23—1000-Kilowatt, 25-Cycle, Synchronous Booster Rotary Converter

Rotary Converters, 25-Cycle Types

Rotary converters, as used for railway and lighting service from 25-cycle systems, are usually of the three following types, viz., synchronous booster, induction regulator, or split-pole converters.

Considerable difference of opinion exists regarding the merits of these several types of converters, making it inadvisable for the committee to make any recommendations as to choice of type at this time. In many recent installations it is

noted that the synchronous booster converter has been selected as most desirable for the particular service to be supplied.

All of these converters have been operated in the past at relatively low speeds, but with the inclination to higher speeds; the introduction of commutating poles has been of material assistance in preserving the good commutating qualities naturally inherent in 25-cycle rotaries.

Rotary Converters, 60-Cycle Types

There is an increasing demand for 60-cycle converters for both railway and lighting service, and as soon as the manufac-

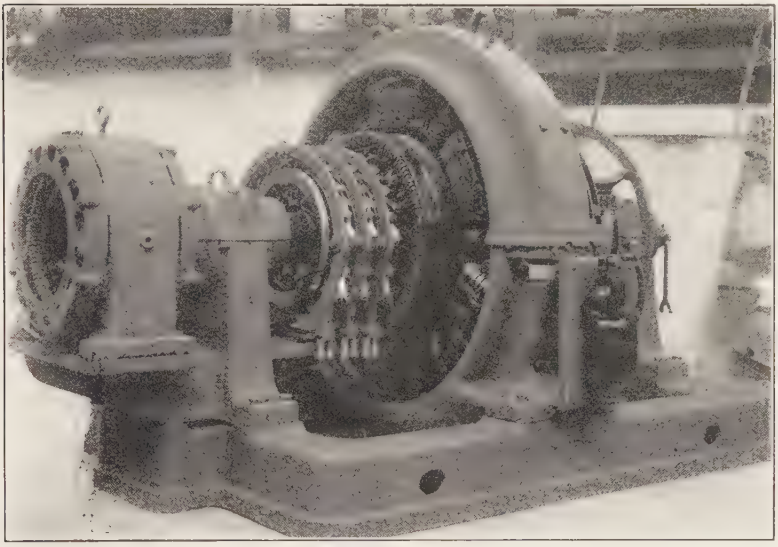


Fig. 24—1500-Kilowatt, 25-Cycle, Commutating Pole Rotary Converter

turers have demonstrated the reliability of this class of apparatus, 60-cycle converters will come into more common use. That they are already being used to a considerable extent is indicated by the report of one manufacturer, who advises that the sales of 60-cycle converters have exceeded those of the 25-cycle type during the past year.

While the use of 60-cycle converters is being persistently urged by the manufacturers, yet, when asked regarding performance guarantees, only one of the several manufacturers who

appeared before the committee was willing to positively guarantee the performance of 60-cycle converters to be equally as satisfactory as that of 25-cycle converters, in capacities up to 2000-kw.

This statement indicates progress and the committee urges the further attention of manufacturers toward improving the operating characteristics of this class of apparatus, to make it possible for operating companies to consistently take advantage of the higher efficiency and lower cost of such equipment, without feeling that its use is going to introduce unsatisfactory operating conditions.

Vertical rotary converters are now available in large sizes, the development of a successful roller bearing having done much in this respect to assist in the production of a satisfactory unit.

Lubricating brushes for use on the collector rings of large converters have been found absolutely necessary to their successful operation in some locations, and are a detail which should be considered in purchasing such apparatus.

Motor Generators

There appear to have been no new developments in motor-generator construction during the year, other than an increased tendency to higher rotating speeds. Induction and synchronous motors are used indiscriminately for driving these units, but full consideration should be given the valuable characteristics of synchronous motors as affording means for power-factor correction when they can be used in favorable locations.

Motor generator sets where supplying direct-current lighting systems, include generators of the following types:

One two-wire generator to connect to outside wires of three-wire systems;

Two two-wire generators, each to be connected between the neutral and outside wires of three-wire systems; or,

One three-wire generator arranged to connect with the outside wires of three-wire systems, with a neutral connection derived from a compensator.

These three types of generators are well known, but attention is called to the limitations of the three-wire generator, in which the neutral capacity is limited to the amount afforded by the design of the compensator, a feature which is undesirable for operation on large direct-current systems.

Advocates of motor generators versus 60-cycle rotary converters still contend for their favorite apparatus, but, as noted in the discussion, increased reliability in 60-cycle converters bids fair to make the use of motor generators attractive only in situations where extensive power-factor correction is required.

Frequency Changers

In the supply of 25 and 60-cycle service from the same generating system, frequency changers form the connecting link between such systems. Units of this character, as large as 8000 kw, have been placed in service during the past year and are giving excellent results. Frequency changers may be either of the induction or the synchronous type, the advantage of the latter type being its adaptability to operate in either direction to change frequency.

In the synchronous type it is customary to include a squirrel-cage winding in the pole faces to make the motor self-starting, as well as to prevent hunting when in operation. The smaller and medium units up to 2000 kw are usually started through a compensator, but in the larger sizes it is advisable to provide an induction motor for this purpose; or, better still where possible, use a direct-current motor for starting, or a direct-connected exciter arranged for use as a starting motor.

Where synchronous motors are started through compensators, automatic oil-switches should be provided on both sides of the compensator.

The induction type of frequency changer is started by cutting out resistance in the wound rotor, and where the speed of the unit must be regulated to synchronize with other machines in the station, resistances of considerable size arranged for convenient control must be provided, in order that the speed of the motor may be regulated.

When remote-controlled contacting devices are used for regulating the resistances, provision should also be made for manual operation in case of the failure of control current.

Special forms of oiling devices are noted in use with large sizes of horizontal frequency changers, their object being to reduce starting currents by introducing oil under pressure beneath the shaft, thereby floating the shaft on a film of oil. This

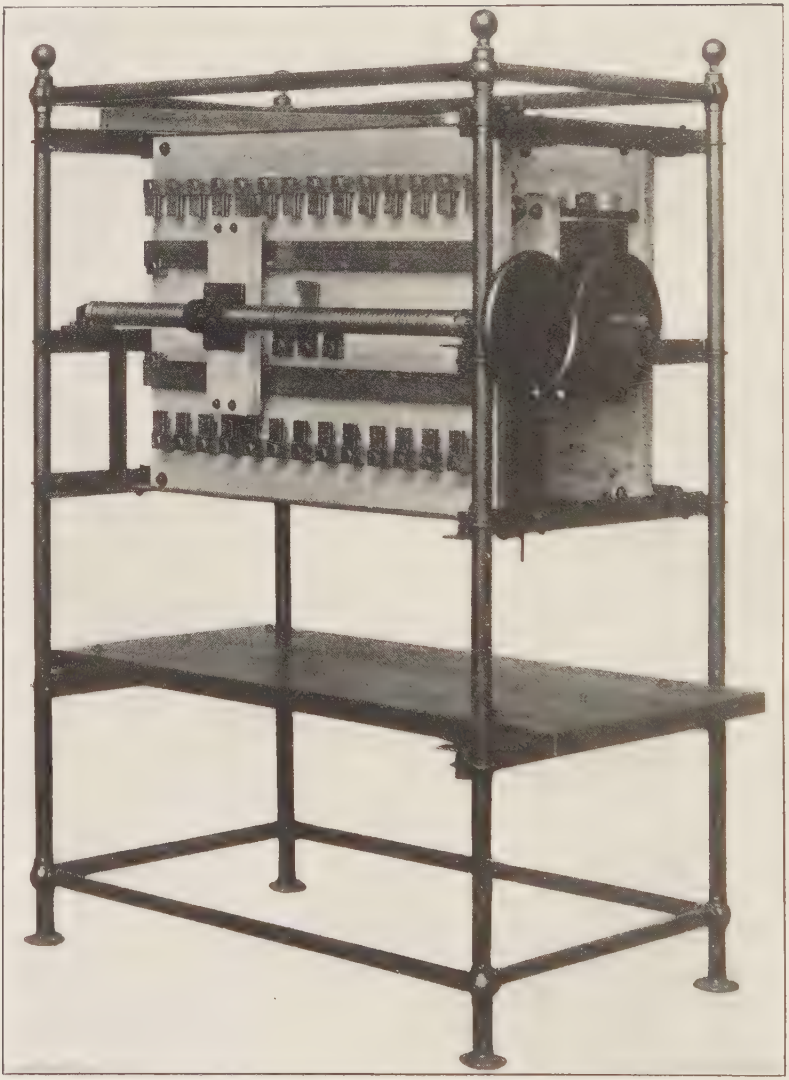


FIG. 25—MANUALLY OPERATED CONTACTING DEVICE FOR STARTING RESISTANCE

construction frequently results in a reduction of 80 per cent in the starting current required as compared with machines not so equipped.

Where two or more frequency changers are to operate in parallel, the motor ends being supplied from a common line, provision must be made for the generators of the sets to share the load. This is accomplished by one manufacturer by providing some of the units in a station with means for rotating the frame supporting the stator, until the proper position is found to give the right phase-relation on the generator end for properly dividing the load.

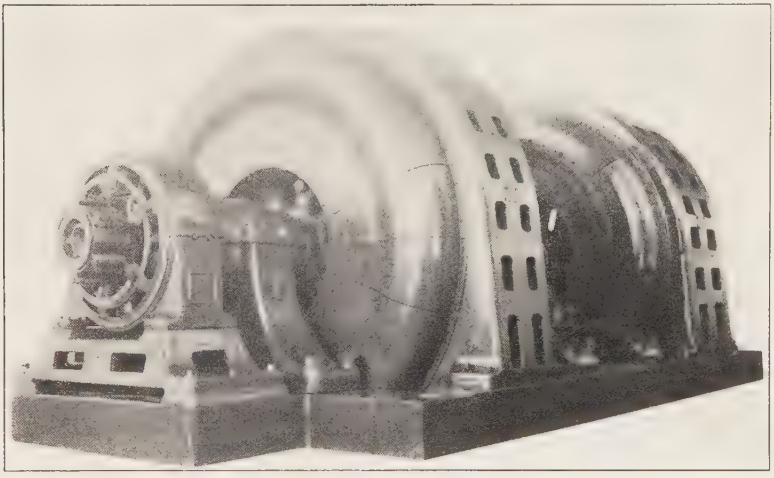


Fig. 26—7000-Kilowatt, 60-25-Cycle Frequency Changer

Frequency changers of the vertical type equipped with roller bearings are now available in sizes up to 6000-kw, and possibly larger. Reports of their operation indicate uniformly satisfactory service and this type of unit has much to recommend it where space is limited.

Substation Equipment

The equipment of a transformer, motor-generator or rotary-converter substation, should provide units of sufficient number and size to carry the maximum load without taking advantage of the two-hour overload rating of all machines. Such stations

should contain enough apparatus to carry the station load even though one unit be disabled.

Such storage battery capacity as may be available in reserve should not be considered in designing station equipments, but should be held at all times purely for emergency purposes.

Moderate speed apparatus is desirable, but the question of speed should always be weighed against cost, and decision reached after consideration of the performance record of higher speed apparatus. Specifications should be based on temperatures, and the maximum temperature of the station in which the apparatus is to be placed should be taken into careful consideration.

End-play and speed-limiting devices with circuit-breakers should be used on all machines where the failure of field current may speed up the machine and wreck the apparatus. The development of the mechanical end-play device without magnetic controlling mechanism seems to have proved eminently satisfactory.

The design of bearings for motor generators, converters or other station machinery is of great importance and is undergoing so many and such rapid developments, that the committee makes no definite recommendation beyond suggesting to purchasers of apparatus, that performance specifications should be very broad to permit the latest and best construction in that particular line, but that in the final contracts for apparatus involving bearings there should be a very clear understanding as to the construction and accessories, if any, that are involved with such bearings, as well as a guarantee of performance.

Mercury Arc Rectifiers

The committee notes no important developments in rectifiers for series circuits, other than improvements in details of manufacture. One company, whose product has been conspicuous for the large number of exposed high-potential terminals, has made substantial improvements in later designs, and while there is room for still further improvement in this respect, the apparatus as at present constructed is reasonably safe to operate.

The irregularities in tube life leave much to be desired with respect to the quality and evenness of the manufactured product, and to make this apparatus popular the manufacturers should

give the utmost attention to the production of tubes of the highest possible quality.

Rumors have reached the committee concerning experiments with large capacity rectifiers for 600-volt, direct-current service, but as yet no definite information is available regarding this much desired development of rectifying apparatus which may possibly take the place of rotating machinery.

Alternating-Current Feeder Regulators

Improvements in feeder regulators the past year have been confined to mechanical details. One manufacturer has substituted a mechanically adjustable permanent brake replacing the

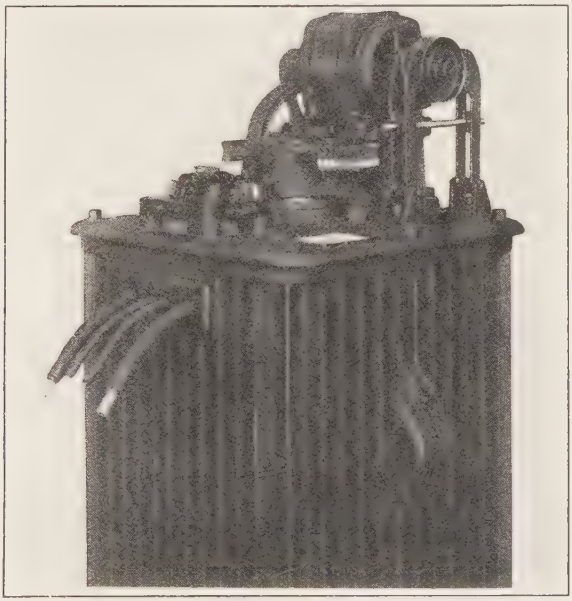


Fig. 27—Induction Feeder Regulator Equipped with Mechanical Brake

magnetic brake formerly used, this change improving the operation of the regulator and at the same time eliminating the objectionable noise developed by the operation of the magnetic brake. The construction of relay control devices has been improved by the addition of damping devices to prevent excessive operation of the regulator in attempting to compensate for rapid minute changes in voltage.

Auxiliary switches are now provided in the contact-making voltmeter, whereby, as soon as the circuit to which it is connected is interrupted, the regulator is caused to assume the position of maximum buck instead of maximum boost, as was formerly the case.

The B. R., or step-by-step type of regulator referred to in last year's report, has been further developed and is now offered in an improved form, in which all defects noted in the past operation of this type of regulator have been corrected. Each regulator is now provided with its own individual motor, this change in construction greatly facilitating its installation, as compared with earlier models.

The choice between induction and step-by-step types of regulators should be made to conform with the service required of such regulators. In extreme cases the step-by-step type, on account of its higher speed characteristics, may be necessary to regulate rapidly fluctuating loads, while under ordinary conditions the induction regulator will perform satisfactory service.

Electrolytic Static Dischargers and Lightning Arresters

The use of aluminum arresters and dischargers has shown a marked increase during the year, indicating greater confidence in their merits. Some failures have been reported under conditions which have led the manufacturers to consider changes in design to increase the capacities of the arresters. The changes suggested include increased spacing of cones and the use of an insulating shield between the cones and the containing tanks.

Observation of the character of the charging arc has been the means of determining the condition of the arrester, but as this is at times deceptive, the use of an ammeter in the charging circuit is recommended as a more reliable means of determining the condition of the arrester.

Troubles have developed from deterioration of the elctrolyte due to the appearance of a fungus growth in the electrolyte after the arrester has been in service for a time. The manufacturers are now prepared to furnish a germ-proof electrolyte, which will be free from trouble of this nature, and will in a measure remove one of the causes of trouble with this apparatus.

A modification of the electrolytic arrester called a surge protector has been developed to eliminate the effect of surges or

rises of potential due to switching movements in systems including underground cable installations. The committee has no information regarding the reduction of this device to actual practise, other than some experiments which have been made in certain locations, and therefore suggests this as a pertinent subject for consideration by the incoming committee.

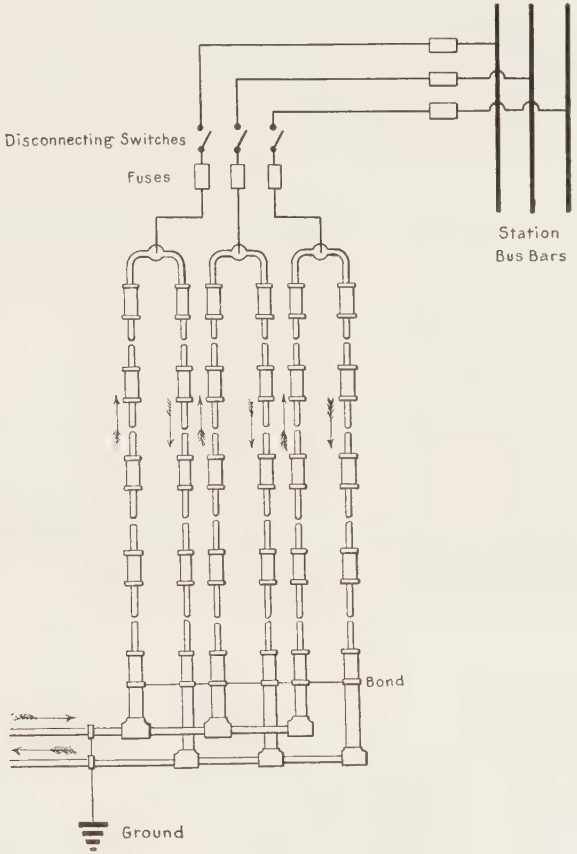


Fig. 28—Typical Water-Leak Arrester

European engineers have as yet made little use of the electrolytic arrester or discharger, preferring the water-leak form of discharger. This type of discharger while simple in construction, as shown by illustration, is said to be effective as used, and possibly should receive consideration in locations where the electrolytic arrester cannot be used to advantage.

The committee calls attention to the indifference to the personal hazard in aluminum arrester installations. Suitable guards should be provided in all cases to prevent actual contact with live conductors or terminals.

Warning is given of the fire hazard incident to the use of aluminum arresters, due to expulsion of oil from the tanks, in case of an arrester failing to carry off a discharge. The same precautions as suggested for oil-cooled transformers should be taken to prevent oil from spreading.

High-Tension Switchboard Wiring

The committee recommends that all high-tension switchboard wiring be subjected to high voltage tests before use. It is suggested that such tests should approximate at least 2½ times the working pressure of the system for a period of at least 5 minutes, and preferably for 30 minutes.

All cable used for switchboard wiring should be purchased under rigid specifications covering electrical and mechanical characteristics, bending and voltage tests. Varnished cambric appears to be the insulation most favored for this class of work and should preferably be protected by a slow-burning outer covering, when installed without the protection of lead sheath. Careful attention should be paid to methods of installation, such as separation of conductors, freedom from loops, stability of supports, accessibility for repairs or renewal, etc.

Discussion is invited on desirable construction methods which may be employed in switchboard wiring.

MISCELLANEOUS NOTES

High-Tension Direct-Current Transmission

High-tension, direct-current transmission, as practised in Europe under the Thury system, has been uniformly successful, and new installations are constantly under consideration.

At present, at least one system is operating at a pressure of 57,600 volts, employing direct-current generators in series, each rated at 3660 volts.

The simplicity of this system, as regards both construction and operation of generating and transmission equipment, is worthy of note, and may possibly be of interest to some members of the Association.

Arcing Ground Suppressor

This device represents one of the advances in the industry which has had substantial tests during the past year on at least two important systems. In a paper presented before the American Institute of Electrical Engineers in 1911, by Prof. E. E. F. Creighton, the construction and operation of the device was explained in detail, as well as the results of tests on the transmission system of the Southern Power Company. Without attempting to give any detailed description of the device, it will suffice to state that its principal object is to establish a solid ground-connection in shunt with an accidental line ground, in order to extinguish any arc which may be established at the fault, thereby extinguishing such arc, upon which the ground-connection established by the suppressor is automatically broken, thus clearing the system of faults, unless the line voltage is able to re-establish the fault when the suppressor has acted to open the ground made through its action. If such should be the case, this suppressor immediately grounds the line again permanently until the system is cleared of trouble, after which the suppressor switch must be opened manually to clear the system of the ground made by the suppressor.

The apparatus is apparently suitable for use on both overhead and underground systems, and the committee believes it well worthy of investigation by member companies of this Association whose operating troubles are such as to require relief of the character afforded by this device.

Portable High-Potential Cable-Testing Set

Mention was made in the 1911 report and a detailed description given of a portable cable-testing equipment which had been purchased by the Boston Edison Company. During the past year, this apparatus has been placed in service and valuable experience obtained from its use in testing a large amount of cable. The set as built includes a three-phase motor driving a single-phase generator; a step-up transformer and a variable reactance in multiple with the low-potential side of the transformer. In the operation of the set the reactance is used to balance the capacity currents, in order to reduce the kva demand on the generator. The capacity of the set, 800-kva, is suitable to test at least 5 miles of 3-conductor 4/0, 15,000-volt, 7-32 in. by

FIG. 29—BOSTON CABLE-TESTING SET

FIG. 30—BOSTON CABLE TESTING SET

7-32 in. paper insulated cable to 30,000 volts for periods of one-half hour. Experience shows that when testing cables which produce a substantial load on the equipment, the wave-form of the testing current is not distorted, but when testing short lengths of cable involving small loads on the apparatus, certain variations in the wave-form occur which are undesirable.

These effects have been studied by means of the oscillograph, and while absolutely definite conclusions have not been reached it seems desirable to use a testing equipment of smaller capacity in minor tests, the purchase of which is under consideration.

It will be noted from the illustrations that the apparatus is mounted on two electric trucks conforming to the company's practise to employ electrically-driven conveyances. These trucks are each of five tons capacity, capable of running 30 miles over good roads on a single charge.

The company is systematically testing all the cable now in use on its system, as well as all new installations, and from the results obtained in eliminating weak places in the cable system, the substantial expense incurred in the purchase and operation of the equipment is more than justified.

Electro-Mechanical Signals

The committee's attention has been called to the recent installation of an electro-mechanical signalling system in the new generating station of a large railway company. The principal claims for the device are its facilities for making an absolute record of all orders transmitted through it, thereby obviating mistakes.

In addition to visual signals, the apparatus is arranged to give audible signals to attract the attention of operators at a distance. As installed in the station referred to, the apparatus is capable of transmitting twelve different orders, and the master switchboard instrument can care for the signals for twelve generator units. An illustration of the switchboard instrument is given from which some idea of its appearance may be gained.

Instrument Equipment for Switchboards

The great need for simplifying and reducing the amount of apparatus now used in the construction of switchboards has led

FIG. 31—ELECTRO-MECHANICAL SIGNALLING DEVICE

the committee to study the question. For the purpose of inviting discussion on this subject, there follows a tabulation of what appears to be the standard practise of the larger companies in providing instrument equipment for switchboards for three-phase systems. Instruments for two-phase systems while of the same types will be varied in number from those enumerated in these lists.

SWITCHBOARD INSTRUMENTS FOR ALTERNATING-CURRENT GENERATING STATION

	System Neutral Grounded	Non-Grounded
Alternating-Current Generator		
Alternating-current ammeters in phase wires	3	3
Alternating-current ammeters in neutral	1	0
Direct-current ammeter in field	1	1
Alternating-current voltmeter	1	1
Power-factor indicator	1	1
Polyphase indicating wattmeter	1	1
Polyphase integrating wattmeter	1	1
Reverse-current relays	3	2
Potential transformers	2	2
Series transformers in phase wires	3	2
Series transformers in neutral	1	0
Outgoing Three-Phase Feeder		
Alternating-current ammeters	3	3
Alternating-current voltmeter	1	1
Power-factor indicator	1	1
Polyphase indicating wattmeter	1	1
Polyphase integrating wattmeter	1	1
Time-limit relays	3	2
Potential transformers	2	2
Series transformers for operating relays	3	2
Series transformers for operating instruments	2	2

Series transformers for relays may be omitted in systems of moderate capacity, if registration of instruments is satisfactory with relays included in the instrument circuit.

Apparatus on Busses—
- Ground detector
- Frequency indicator
- Synchroscope
- Potential transformers

INSTRUMENT EQUIPMENT FOR SUBSTATION SWITCHBOARDS

High-Tension Switchboards

	System Neutral			
	Grounded	Non-Grounded	Grounded	Non-Grounded
Incoming Three-Phase Feeder				
Time-limit relays	3	2		
Series transformers to operate relays	3	2		
No instruments				

	H. T. Side		L. T. Side	
Step-Down Transformer				
Alternating-current voltmeter	1	1	0	0
Polyphase indicating wattmeter	1	1	0	0
Polyphase integrating wattmeter	1	1	0	0
Potential transformers	2	2	0	0
Series "	3	2	3	2
Time-limit relays if used	3	2	3	2

	System Neutral			
	Grounded	Non-Grounded	Motor	D.-C. Generator
Motor Generator, Alternating-Current to Direct-Current				
Alternating current voltmeter	1	1		
Power-factor indicator	1	1		
Polyphase indicating wattmeter	1	1		
Polyphase integrating wattmeter	1	1		
Time-limit or instantaneous relays	3	2		
Potential transformers	2	2		
Series "	3	2		
Direct-current ammeter	..	..	{ 1 on 2-wire gen. { 2 " 3 " "	
Direct-current circuit-breaker			{ 1 on 2-wire gen. { 2 " 3 " "	
Speed-limit attachment to direct-current circuit-breakers		..		1
Voltmeter and plug for all direct-current generators	..	..		1

	Motor		Generator	
	System Neutral		System Neutral	
	Grounded	Non-Grounded	Grounded	Non-Grounded
Frequency Changer, Alternating-Current to Alternating Current				
Alternating-current voltmeter	1	1	1	1
Alternating-current Ammeter	1	1	1	1
Power-factor indicator	1	1	0	0
Polyphase indicating wattmeter	1	1	0	0
Polyphase integrating wattmeter	1	1	0	0
Time-limit relay	3	2	3	2
Potential transformers	2	2	2	2
Series "	3	2	3	2

	Motor System Neutral Grounded H. T. Side	Motor System Neutral Non-Grounded H. T. Side	Generator L. T. D.-C. Side
Rotary Converter			
Alternating-current Ammeter			
Power-factor indicator	1	1	
Polyphase indicating wattmeter	1	1	
Polyphase integrating wattmeter	1	1	
Time-limit relay	3	2	
Potential transformers	2	2	
Series transformers	3	2	
Direct-current ammeter	0	0	1
Direct-current circuit-breaker	0	0	1
Speed-limit attachment to direct-current circuit-breaker	0	0	1

Instruments on High-Tension Busses

Ground detectors
Synchroscope

Alternating-Current Distribution Circuits

Type of Circuit	Single-Phase	3-Phase 3-Wire	3-Phase 4-Wire
Compensating voltmeter	1	1	3
Single-phase indicating wattmeter	1	0	3
Polyphase " "	0	1	0
Contact-making voltmeter for feeder regulator	1	1	3
Time-limit or instantaneous relays	1	1	3
Potential transformers	1	1	3
Series "	1	1	3

Instrument on Busses

Ground detector

Mercury Rectifier

Primary Side—
Single-phase indicating wattmeter
Single-phase integrating wattmeter
Time-limit or instantaneous relay
Potential Transformer
Series Transformer
Secondary Side—
Direct-current ammeter
Open-circuit relay
Series transformer

Direct-Current Switchboard

Ammeters	1	2
Direct-current Generator—		
Circuit-breaker	1	2
Balancer or Booster Set—		
Ammeters	1	2
Direct-current Feeder—		
Ammeters	1	2
Storage Battery—		
Ammeters (center scale)	1	2
Ammeter (in neutral)		1
Recording voltmeter	1	2
Instruments on Busses—		
Voltmeters	1	2

General Notes

Testing terminals should be provided in the secondary circuits of all potential and series transformers to facilitate testing of instruments.

Indicating and integrating wattmeters may be added to the generator ends of frequency changers and to the direct-current ends of alternating-current to direct-current motor generators and rotary converters if such records are desired. Likewise integrating wattmeters may be added to the equipment for alternating-current distribution circuits if desirable. In this tabulation reference to number of busses and switches for station apparatus and feeders has been purposely omitted.

DISCUSSION

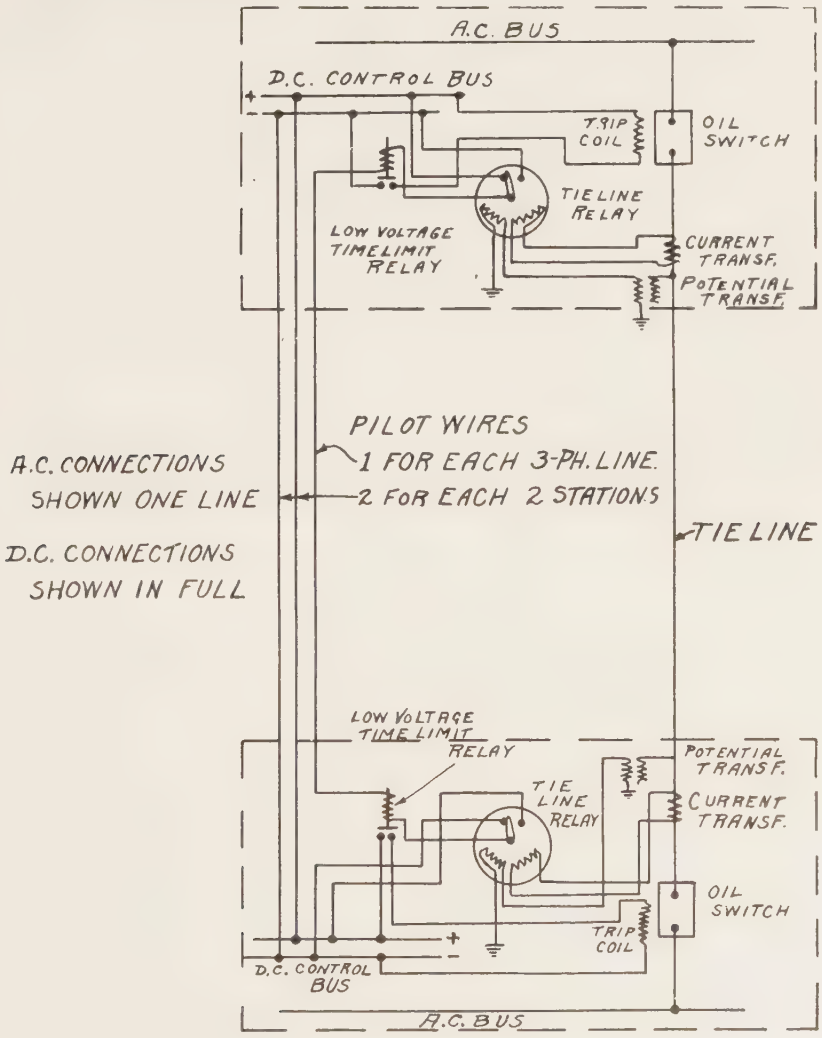
Mr. W. N. Ryerson, Duluth: On page 561 of the Report various methods for driving exciters are mentioned, and I think it will be interesting to call attention to one method that has been used here as well as in the east in water-power plants, and that is, driving the exciter by a water wheel with the addition of an induction motor on the same shaft. This method does away with the necessity for a governor on the exciter wheel and takes care of conditions very nicely. My experience would lead me to differ from the conclusions of the Committee in regard to the advisability of installing reverse-current relays on exciters. Personally —I am speaking for myself only—I would rather take the chance of tying the exciters directly onto the bus-bars.

On page 598 the Committee enumerates a list, which is very formidable, of instruments on the switchboard. It seems to me that we are getting away, especially in large switchboards, from the desirable end in view, which is to keep switchboards down to the minimum in size and equipment. There are a lot of useless instruments and a lot of money wasted on those instruments, on the average switchboard. If additional instruments are wanted, for instance, three ammeters, one in each leg of the circuit, why not put two of them on the back of the board? They can be looked at there whenever needed, which will not be often. In that way the instruments on the front of the panels are kept down to an absolute minimum.

Mr. T. H. Yawger, Rochester, N. Y.: The member companies are up against the problem of furnishing an uninterrupted

service, which, with the present type of relays, they are unable to do. In case of trouble on any one feeder a part or the whole of the system is liable to be kicked out.

The General Electric Company recently developed a modification of the Merz-Price system, which Mr. Stone did not bring out, and just before I left home we installed and tested this device out on our alternating-current network. The following figure will illustrate it.



In the larger cities the underground connecting network is ordinarily tied in at various generating and substations by two or more tie lines. Under the present operating conditions with available relays, a fault on any one of these particular cables ordinarily operates breakers on other lines beside the one on which the trouble arises. This new relay is a marked advance in the industry, as it does not operate on overload conditions but only on a reversal of current due to a fault, and thus permits the network to be tied together solidly. This system requires for its proper installation a single pilot wire for each cable, the pilot wire being connected to trip coils, which are energized only by a reversal of current in the main feeders, and in turn operate the above-mentioned galvanometer. This works very successfully, and we have about decided to equip our entire system under this scheme and tie our network together solidly, so that there will be no chance of any of these feeders kicking out from overloads or short-circuit on any but that part of the system in trouble.

This system, while rather costly, is not as expensive as might be supposed, requiring only a single low-voltage pilot wire between stations. A multiple telephone cable for a number of feeders and existing current transformers can be used. This device, I think, bids fair to solve a great many of our troubles. As we are operating at present, a fault on any one feeder is liable to kick out a number of them and thus disturb the whole system.

Mr. S. Q. Hayes, Pittsburgh: In connection with the Merz-Price relay system let me say that it is not essential to connect the current transformers in opposition. In certain cases they have been connected with the two transformers in series and the relay instead of being a current relay is practically a potential relay. We get just the same effect.

It has occurred to me in connection with this question of reactance, the external reactance which Mr. Stone brought out, that if the breakdown came in the external reactance instead of in the machines, there would be some trouble due to the other part of the station feeding into a fault in that external reactance. It seems to me that if each machine is provided with its own reactance, either internal or external, the amount of power flowing into a short-circuit will be limited.

On page 561 the question of using auto-transformers to step up the voltage is discussed. Auto-transformers will be cheaper

than two-coil transformers where the ratio is low, say about one to two; but where you want to have a fairly high transformation ratio, one to five or higher, there is comparatively small difference in cost between it and the two-coil transformer, while the latter has the additional advantage that a ground on one of the high-tension lines does not raise the voltage of the generator. Relative to the construction of iron-clad switch gear, Mr. Stone mentioned the fact that his European company has a complete line of iron-clad switch gears. It should also be noted that the British Westinghouse Company has a complete line. [Laughter.]

The reference to outdoor circuit-breakers on page 576 recalls the fact that on the lines of the Southern Power Company these are actually operated at 100,000 volts instead of 88,000 volts.

The list of switchboard instruments given on pages 598 and 599 is an exceedingly formidable one. The company with which I am connected instead of providing three ammeters in the three-phase generator circuit, as mentioned here, in a great many cases furnishes one ammeter with a little plugging device so that it can be connected in any phase. Instead of providing a voltmeter in each generating circuit as mentioned, they merely provide one voltmeter connected to the bus and another voltmeter that can be connected to any machine. Moreover, they seldom furnish both power-factor meter and polyphase indicating wattmeter on one panel, although in certain cases they do so.

Mr. C. W. Stone, Schenectady: The report is so valuable and voluminous, that I have a great deal to say, and I hope that the Chairman will not hesitate to ask me to stop at any time to give others a chance, if I talk too long.

On page 550 reference is made to the operation of substation apparatus for both lighting and railway service. The practise in this country is somewhat different from that abroad. In this country for lighting service, 240 to 300 volts, certain machines are used. Other machines are used for railway service from 500 to 600 volts. Abroad the same voltage is used for both classes of service. It seems to me that it might be advisable to arrange our machines so that they can be operated in series for railway service, and in multiple for lighting service, the series fields being disconnected. This would result in a minimum cost for substation apparatus, and in a higher load-factor for all substation apparatus and the high-tension feeder system. It is my personal

opinion that too little attention has been paid to this phase of the situation in this country. In order to get substation apparatus at the lowest cost and maximum capacity installed in minimum space, we should build a type of rotary converter, making use of two field structures, two armatures and two commutators with but a single set of collector rings, and a single set of transformers. For instance, a 1000-kw. unit running at say 300 revolutions could consist of two 500-kw. machines coupled together with a single set of collector rings, and could be run at 600 revolutions. At times of light load only one-half of the machine need be used, thus gaining in efficiency; and in case of trouble with one part of the machine, the other part would still be available.

On page 550 there is mentioned the so-called iron-clad switch gear. This is a type of construction which has been used very largely abroad, but to a limited extent only in this country. It seems to me that there must be many places where this gear could be used to advantage.

On page 556 the question of reactance has been brought up. This is a subject of tremendous importance at present because of the very large capacity of our present type of central station. The installation of reactances is, of course, more important on the low-frequency systems, such as 25 cycles, there being less demand for their installation on 60-cycle systems, as in the latter case the generators themselves have higher internal reactance as well as the transmission lines and connections. While I believe that external reactances are perhaps the best devices to use in existing installations, in new installations another type can be used to advantage. Numerous installations have been made of this type of protective device. I refer to auto-transformers used to step up the generator potential, and at the same time designed with high internal reactance for protection against short-circuits, and also so constructed that at times of short-circuit the iron will not become saturated. This form of protection makes it possible to design large turbine generators with high internal reactance, and on account of the lower potential makes the generators inherently safer. It is, however, a question of expense and space as to which system is used. To my mind it is preferable to build generators with as high internal reactance as possible without complicating the design too much; and high

external reactance in one form or another should be used, as it acts as the safety device in case of trouble with any one of the generating units. If one of the generating units is damaged its reactance is eliminated, and the amount of current which can flow into this damaged machine before it is disconnected from the system is limited only by its capacity and its reactance in series.

On page 560 mention is made of the methods of starting induction generators. There is still another method, and that is bringing the induction generator up to speed with the synchronous machines, simultaneously.

On page 561 no mention is made of an auxiliary exciter system. I believe, although I have a great many friends who do not agree with me—and perhaps many of you will not—that the isolated exciter system is going to be used in large and important systems. When I speak of an isolated exciter system, I mean one which is run absolutely independent of the main generating system. This is usually done by the installation of a non-condensing turbine driving a low-voltage generator. The auxiliaries in the station would then be electrically driven. The steam from this non-condensing main central unit would be taken to the feed-water heaters. One great advantage of this system is that it is all within the control of the operator. It is entirely in the main station, and nothing that happens to the system can possibly affect it, which to my mind is the vital point of the entire system. The objection to electrically driven auxiliaries has usually been that in case they were used and connected to transformers connected to the main system where a short-circuit occurred, the exciter system and the other auxiliaries would usually be kicked out of step, owing to the drop in frequency and in potential. If electrically driven auxiliaries were used with the independent exciter system or auxiliary system no such disturbance could affect it, as there would be no connections with the main system.

I notice in the report that mention is made of speed-limiting devices on an exciter system. I can see no reason whatever for such an installation. I do not believe it is proper to use such devices. I do not see how the motor-driven exciter could run away except possibly because of an open circuit in the shunt field of the exciter and also the opening of the alternating-cur-

rent switch. I think this is rather a remote chance, and if reverse-current relays were used this source of trouble would be eliminated. I do not see, therefore, why we should put on two sets of protecting devices.

On page 571 is discussed the amount of internal reactance in large transformers in stations. I believe it would be desirable to have from four to six, and possibly in some cases, eight per cent, internal reactance. On that same page, paragraph 3, mention is made of high-potential transformers. I want to speak just a minute and express my idea of the proper method of operating high-potential transformers of above 75,000 volts. In the first place, I do not believe that we should use transformers on potentials higher than that unless we operate the system as an isolated delta system, instead of as a grounded Y system. I do not believe that where we use such high-potential transformers there should be any high-tension switching whatever. My reasons are as follows: In the first place, low-voltage transformers up to 75,000 volts have fairly high internal reactance, and no appreciable capacity; having high internal reactance, disturbances on the line are usually prevented from entering the transformer; having but little capacity, there is no resonating effect and consequently the entire shock to the transformer is on the end turns, which we can readily protect by extra insulation. In transformers of large kilowatt capacity, however, and of high voltage, we get a condition where the reactance is not so high, and in addition to that we have high internal capacity. Consequently a disturbance which is more likely to occur on a high-potential system is not prevented from entering the transformer and, in addition to that, the high internal capacity of the transformer may cause resonance with the line and high internal rises somewhere in the transformer at places where they cannot be protected. We do not always know where this point is; it shifts in accordance with the frequency of the disturbance. I have seen high-potential transformers of 100,000 volts broken down in almost every possible point in their windings. We cannot insulate entirely throughout the transformer as we can on the end turns, and it would afford no protection. I have seen rises of 200 to 300 per cent above normal line potential in some little isolated part of the transformer. With the grounded Y system the entire shock is concentrated on the one

transformer connected to the wire in trouble. With isolated delta connection, however, this trouble is divided between two transformers. With it an arcing ground suppressor can be used which will in most cases cut out the particular wire in trouble before any serious damage is done to the transformer. This is not true in the grounded Y system.

High-tension switching always causes a disturbance, because even with oil switches the first act is to open the arc between the contacts. In almost every case that arc is re-established and then broken, and, in some cases, re-established two or three times in cases of very serious disturbance. That always means high voltage disturbance on the system. With the transformer disconnected from the system, the capacity current from the transformer has no place to discharge itself, and consequently must discharge some way inside the transformer and thus causes a spill-over or a complete breakdown, as the case may be.

On page 580 attention is given to the single-turn current transformer. I believe that this type of transformer is valuable for use in the large systems. It is the only reliable way of making a transformer which is safe on high potentials with systems of considerable capacity where the current in case of trouble is very great.

On page 581 mention is made of potential transformer fuses. Considerable advance has been made in the last year in the design and building of this type of fuse. I think we can safely say that we now have a reliable fuse for voltage up to 20,000 for the 200-watt potential transformer.

On page 582 the Merz-Price system of protection is mentioned. This system if adopted would mean a complete revolution of all of the ideas of American engineers, who are prone to use what is called the radial system of feeders. To properly use the Merz-Price apparatus we should adopt a system of feeders similar to that used by Mr. Merz himself, feeders running from the generating stations to the substations and tie feeders between the substations; in other words, practically a complete ring system. It is easy to see that in this type of system the use of the Merz-Price relay is justified. In the radial system, however, the expense of this relay would be almost prohibitive.

There is one matter in connection with this which I do not find mentioned here. In case you want to use the Merz-

Price system of relay protection you must understand that the present type of current transformers cannot be installed, as they are connected together in such a way that no current flows under normal operating conditions. This is equivalent to an open-circuit condition on series-type transformers, which would, of course, burn them out under the exciting current. In other words, the transformers to be used must be designed for open-circuit operation.

In connection with the very ingenious testing outfit which the Boston Edison Company has developed, I want to point out a possible improvement. Instead of building the reactances for low potential for connection on the low-potential side of the transformer, they could be built for high-potential service and installed on the high-potential side, thus saving capacity in the transformer. It is desirable in all cases when using such testing outfits to provide a non-inductive load in addition to the load of the cable or apparatus which you are testing, as in this way you can get more stable operation in the outfit. That is, if the load is entirely a cable load, the current is all leading, and it is difficult to maintain the potential of the generator sufficiently constant to make good readings of the instruments. With a non-inductive load, however, such as an ohmic resistance, you can maintain conditions long enough to make voltage readings.

There was one thing more I want to speak of, and that is the question of unbalancing when rotary converters are used for obtaining the neutral from the center of the transformers. Machines have been designed, and are in operation, where the whole load current on the machine is taken between the positive brush and the neutral. In other words, a 500-kilowatt machine of 300 volts could be operated as a 250-kilowatt machine at 150 volts, taking the entire load off on one side of the machine. [Applause.]

Mr. Elden: I assure you, gentlemen, that the Committee fully appreciates your discussion on this Report and in reply will answer such points as have been raised.

The suggested use of speed-limiting devices on exciters is intended to apply exclusively to compound-wound, motor-driven exciters where the conditions are favorable to their running away upon the occurrence of certain kinds of trouble. With such installations reverse-current relays are likely to increase the cer-

tainty of avoiding troubles due to reversal of current or failure of alternating-current supply, although it is granted their value is entirely dependent upon their reliability of operation, a feature not always present in actual service.

The report in referring to the Merz-Price system of protection suggested that it was particularly applicable to the protection of alternating-current feeders. In passing, it should be noted that there are probably at least 100 different methods of connecting the system of relay control for the protection of all kinds of generators, converting or transmitting apparatus employed in central-station service.

In certain cases, as Mr. Stone has said, standard current transformers are not suitable for use where the balanced potential method of control is employed. A modification of the current-balanced method of connection for the protection of step-down transformers, generators and similar apparatus, may employ standard current transformers with success, through the introduction of balancing transformers, thus permitting the operation of the current transformers on a closed circuit. At least two such applications of the current balancing method of protection are actually in service in stations of two of the larger companies.

I note that Mr. Yawger is making use of still another modification of this system with success. In Mr. Yawger's case the result of adopting this protection is to afford an opportunity for the maximum use of line investment which obtains from the operation of feeders in multiple at both generating and substations.

The Merz-Price system is of further value in the construction of long lines supplying a number of substations, in that it permits with perfect safety the extreme ends of such lines to be connected together to form a closed ring, or cross connections if necessary at any point across the ring or between separate ring systems, thus conserving in the fullest degree the capacities of the lines comprising such a system, as well as insuring continuous service.

It may be of interest to note that the cost of the pilot-wire cable for underground and overhead construction as used in England amounts to approximately $1,000 per mile, a considerable item in a system employing a large number of cables. Auxiliary apparatus, such as relays and current transformers used

with this system, are no more costly than similar apparatus in regular service in our own stations.

The list on switchboard instruments included in the Report as given is a typical example of standard practise in the systems of the larger companies. It is obvious that where certain data are not required for operating or statistical purposes, some of the equipment listed may be omitted, although in almost every case the series and potential transformers must be retained for important reasons.

THE CHAIRMAN: The next number is the Report of the Committee on Underground Construction, Mr. W. L. Abbott, Chicago, Chairman.

REPORT OF THE COMMITTEE ON UNDERGROUND CONSTRUCTION

The following report of the committee is the result of investigations based largely upon inquiries sent to a number of the larger operating companies in this country, and deals with what may be considered the most live questions of the day coming within the range of the functions of this committee. Specifically it considers the following items:

Alternating-Current Underground Distribution.

Manhole Construction.

Electrolysis.

High-Tension Cable Data and Specifications.

The subject of alternating-current underground distribution was chosen on account of its growing importance, due to the tendency of municipalities to dispose of overhead lines in their more thickly settled residential districts. From the summary in Table 1 it can readily be seen that so far the system is still young and limited in extent, but possessed of latent possibilities which in time will make it a worthy rival of direct-current underground distribution.

Manhole construction was considered on account of its important bearing on transmission and distribution in general, and on alternating-current underground distribution in particular, determining in a considerable measure its success or failure.

Of all the items considered, electrolysis is perhaps the most important, as it directly concerns the protection of about 25 per cent of the total central-station investments aside from the value of other sub-surface structures, such as gas and water pipes. This subject in the past has not received the attention it merits, largely on account of the nature of the trouble, which requires years for development and is usually first detected in the course of break-downs, the result of irreparable damage caused by electrolysis.

High-tension cable data and specifications are likewise subjects which have not had due attention. This is shown by the absence of a standard form of cable specifications and the equally conspicuous lack of data in regard to the carrying capacities of different size cables. Considerable difference of opinion is found to exist in regard to various other equally important points.

Replies to inquiries sent out were not in all cases as explicit and complete as they might have been, largely on account of abnormal conditions peculiar to different localities; as a result none of the above subjects can be said to have been covered exhaustively. It is thought, however, that the report as submitted brings to the fore the current practise in the larger companies in this country and will, it is hoped, be the means not only of disseminating information, but also of encouraging critical analysis in a branch in which there is still ample room for constructive ability of the highest order.

ALTERNATING-CURRENT UNDERGROUND DISTRIBUTION

Replies to inquiries pertaining to alternating-current underground distribution were received from twelve of the large operating companies in this country and indicate that, as a whole, comparatively little work along this line has been done, and that the present is the proper moment for the discussion of a subject still in the beginning, but destined to grow at a rapid rate.

The element of cost as well as the inherent difficulties of an engineering character incidental to this method of distribution have so far effectively retarded extensive development of alternating-current underground distribution. Limitations of subways, due to lack of street space and the difficulty of keeping manholes dry, will always be obstacles, while the increased cost of underground above that of overhead distribution will inevitably make the former appear desirable as a method to be resorted to only under stress. Nevertheless, really creditable work has been done by some of the larger companies, notably by the Pacific Light and Power Company in some of the cities along the Pacific coast.

Alternating current underground distribution in general conforms to established overhead practise as far as voltage, character of service and regulation are concerned. In its highest development alternating-current underground distribution commences with single or multiple-phase feeders, which are provided with all the necessary equipment for switching and regulating and run from the substation to the centers of distribution. Here junction boxes are installed through which the feeders connect to the high-tension cable mains, all connections to the boxes

being made with lead-wiped joints. The transformers, preferably of the subway type, are connected to these mains by means of cut-out boxes, various types of the latter being used in different localities. Tie cables are installed between different centers, and in case of break-down of one of the feeders, may be used to carry its load while repairs are in progress.

The method of installing transformers, standard subway types of which are on the market, plays a very important part in the successful operation of an alternating-current underground distribution system. Transformers should be provided with cut-out subway boxes on both primary and secondary sides, if they feed an underground distribution network. If they feed only isolated sections, the cut-out on the secondary side may be omitted. These boxes need not necessarily be fused, as the reports received from a number of operating companies indicate that the fusing of the underground system has given more or less trouble. Several companies recommend the omission of fuses on both the primary and secondary sides, and depend for protection entirely upon the automatic devices in the station. One company does not consider it advisable to fuse the secondary system, but does recommend oil submerged fuses on the primary. The company previously referred to, however, which has the most extensive system of underground distribution of this nature, fuses both sides and reports to be singularly free from interruptions. A brief account of the practise of this company may for this reason be of special interest.

Underground feeders are run from the substations to junction boxes at the centers of distribution. Between two such centers a tie-line is run which in case of failure of one of the feeders is closed to carry its load. Primary mains radiate from these boxes and feed subway transformers, the secondaries of which connect with a secondary network which by means of link cut-out boxes may be sectionalized in cases of trouble or for work caused by extensions and repairs. The only primary fuses installed are those on transformers. Primary fuses are submerged in oil in boxes of different design, some with barriers between phases and others with conductors lowered into porcelain compartments. Of 400 of these boxes in service for a period exceeding four years only three have failed. Arrangements for ventilating manholes have been found not necessary, although

transformers up to 150-kilowatt capacity are installed. In general, experience with this system has been highly satisfactory.

The chief difficulty which all companies encounter more or less is the flooding of subways and manholes. Occasional failures in the cable connections to the transformers have also contributed to the list of troubles in this class of service. No particular precaution seems to be necessary to conduct the heat away from transformer manholes except with large installations, where some companies have provided a cold-air intake at the bottom of the manhole and a vent at the top. These are usually placed alongside an adjoining building, where such arrangements can readily be made. Not more than two transformers of 75 to 100-kilowatt capacity each should be installed in the ordinary manhole.

In general it may be said that 8 watts of transformer losses may be allowed per square foot of wall surface. In moist soil with ventilated chamber 12 watts may be allowed, while under unfavorable conditions not more than 6 watts would be permissible. The roof and floor should be included in the determination of the wall surface.

Inexpensive Construction for Residential and Suburban Districts

The request for a cheap yet good form of construction for suburban districts has failed to bring forth any suggestions from member companies. Nearly all companies report that they have no underground distribution in suburban sections. The committee in its report last year described briefly several systems which were in general use, namely:

Street distribution

Interior block distribution.

Sidewalk distribution.

These systems are fairly well understood, and it does not seem desirable to discuss them further at this time.

The use of armored cable buried directly in the ground has been one means of avoiding the high cost of a conduit or draw-in system. This method has been used by several companies for park and street lighting as well as for sidewalk distribution. The individual conductors of the cable are rubber-insulated, laid up round with jute filler, taped and lead covered. Over the lead is a jute bedding and two layers of steel tape, a finish of asphalted

jute being laid over the steel armor. The cable is laid in a shallow trench, about fifteen inches deep without any protection except where crossing roads or paths, when it is drawn through an iron pipe. Where joints are necessary, they are usually protected by drawing an iron sleeve over them. This type of construction is particularly applicable in city parks, because of the many turns and bends necessary to avoid trees, stones or other obstructions. Under these conditions, it would be almost impossible to construct conduits, owing to the difficulty of pulling cables through the numerous turns made. While this system has given entire satisfaction when installed in city parks and under sidewalks between the curb and house line, the committee would not recommend that a cable of this type be buried underneath a permanently paved street.

Records of Subway Equipment

The matter of keeping complete records of subway equipment is very important, and it should be the duty of every cable and underground engineer to keep a system of records which will enable him to tell at any time the exact amount and the location of installed cable. Nearly all companies keep records in one form or another, giving the location of their manholes, distribution holes, and other sub-surface equipment. Several companies report that while their system of records is not entirely satisfactory, the benefits to be derived from complete records do not warrant the expense which would be involved in a more elaborate system.

Diagrammatic layouts of the conduit system kept in loose-leaf or card form are used by a number of companies. These records are not drawn to scale, but show a diagram of the street with a line to represent the conduit, while manholes are indicated in their proper location by rectangles or other figures corresponding to the shape of the manholes. Measurements are indicated, showing distances between centers of covers and also their location with respect to curb lines. The latter is quite important, particularly in locations where, during the winter months, snow covers the ground. Knowing the exact location of the center of a cover will save considerable time for the cable men when inspecting manholes and locating trouble.

All cables should be properly tagged in every manhole,

these tags to indicate the size, voltage and cable number. The cable tags, made of sheet brass, are about two inches in diameter, and are fastened to the cable by several wrappings of copper wire.

A system of recording subway troubles is also of some value. Interruptions to service caused by the failure of a cable or other equipment should be thoroughly investigated by the foreman or cable man in charge, and a complete report giving full details should be submitted to the department head. If the troubles are numerous and a record of this kind is kept, it will greatly assist in determining what changes are necessary to improve the system. The committee strongly recommends that inspection of the subway equipment be made systematically and it should not be assumed that when the installation is complete it needs no further attention. Cables in manholes should be protected against mechanical injury and employees should be directed not to use them as ladders in climbing in and out.

Table No. 1 contains a summary of data collected in regard to extent of alternating-current systems of distribution, chief causes of trouble, and protective devices in twelve large cities in this country.

MANHOLE CONSTRUCTION AND DESIGN

General

Manhole construction may be classified under three headings:

A—Brick construction.

B—Monolithic concrete construction.

C—Concrete block construction.

The design of each of these three types of construction may be divided into two classes, namely: Design to properly facilitate the training of cables for transmission purposes, and, design to provide for the training of cables for distribution purposes, including the installation of transformers, boxes and other sub-surface equipment.

Type of Construction

Of eleven large operating companies reporting, four use brick entirely for manhole construction, two use concrete, and five use both brick and concrete. Monolithic concrete seems to

be advocated for manhole construction, particularly where a number of manholes of the same size are to be built and where local conditions and the space available in the street will permit the use of a standard form. One of the advantages of the use of monolithic concrete for manhole construction is the fact that common labor may be employed for mixing and pouring the concrete, whereas with brick construction, the services of experienced masons are necessary. Brick construction seems to be very desirable in congested sections where the use of either a wooden or metal form for concrete work would be almost prohibitive on account of the high cost of special forms to meet the local conditions.

One company in the middle west reports that one of the disadvantages in the use of concrete manholes lies in the fact that the soil in many locations is sandy clay, which will not stand unless properly supported by bracing. The result of this soil condition is that in the locations where the absence of other obstructions will permit the use of concrete manholes, the soil would require an outer as well as an inner form, so that the resulting cost would be higher than for brick manholes. The presence of water in some localities at a depth of three or four feet makes it necessary to build brick manholes. In such locations, a manhole of brick can be built by driving sheet piling and using a sufficient number of pumps to remove the water from the hole. The brickwork is started directly upon the sand and the manhole is filled up with sand as the work progresses. This prevents the water which seeps into the hole washing out the mortar of the brickwork.

Concrete blocks have not been used to any considerable extent for building manholes, although this form of construction would undoubtedly be the cheapest if a considerable number of manholes of a standard size were to be built. One reason why this type of construction is not more common is the difficulty of making connections between the manhole and the conduit lines. Concrete manholes are limited to localities in which the underground conditions permit their being built in standard sizes and shapes, and where the ground is of sufficiently firm composition not to require an outer form for the concrete. Moreover, concrete manholes should be allowed at least 48 hours for setting, which practically prevents their construction

in streets with dense traffic. The brick manhole is preferable where irregular shapes only can be used and where a large number of future connections are to be made, it being much less liable to damage by these connections than the concrete manhole.

Roof Construction

Manhole roofs are sometimes built of second-hand T rails laid in two layers crosswise and filled in with concrete. "I" beams and other standard shapes are also used, and sometimes, on moderate spans, concrete reinforced with expanded metal.

Sewer Connections

While cables and other manhole equipment are usually so constructed as to operate successfully when submerged in water, it is desirable to have manholes free of water. Of the companies reporting, all install sewer connections, which are usually provided with a back-trap valve. Drains are particularly necessary for those manholes which contain transformers and other equipment that should not be flooded.

Type of Cover

There are several types of manhole leads in use, both round and rectangular. While a number of companies use a rectangular, the majority of those reporting use a round cover. Some companies use an inner cover, which is fastened tightly to the outer frame by means of a lock-bar and nut and made waterproof by means of a rubber gasket. In some installations this inner cover is intended only for a pan to catch the dirt which falls through the ventilated outer cover. Such pans, however, are not in general use. Ventilated covers are quite necessary in streets where conduits and gas mains parallel each other in close proximity, as there is always danger of gas explosions and fires in the manholes.

When manholes are constructed in unimproved streets, it is well to allow for any uncertainty regarding the exact grade of the finished paving. If, therefore, the roof is built about four inches low and the head casting is brought to the surface by being set on bricks instead of directly on the iron frame, it will allow a space of four inches for lowering the head without disturbing the roof frame in case the grade of the street is changed when permanent pavement is laid. Manhole heads should be set

one-half inch above street grade to prevent surface water draining into the hole.

Waterproofing Manholes

No regular attempt seems to have been made to waterproof manholes except in a few special cases where tarred paper, painted over in the usual manner with standard preparations, has been employed to coat the exterior surface of the manholes to prevent seeping of water. This method of waterproofing has not been entirely satisfactory, owing to the number of corners and outlets, such as duct lines and service connections, around which it is very difficult to make a watertight joint. Concrete manholes, in which the concrete is mixed with some form of waterproofing compound, have been built below tidewater and made quite waterproof. The most satisfactory method of so doing is to keep the manhole as dry as possible when pouring the concrete and to use a rich cement mortar, tamping it carefully. A cement waterproof coating applied on the inside of a concrete manhole has given very good results.

Design of Manholes for Transmission and Distribution Work

Manholes are either two-way, three-way, or four-way according to the number of conduit outlets, which is determined largely by service requirements. For transmission purposes the two-way manhole of elliptical or oblong octagonal shape is well suited, because it provides sufficient wall space for the making of cable joints and at the same time eliminates the necessity for sharp bends in the cable. The three-way manhole on the outlet sides practically follows the lines of the two-way manhole, excepting that the side free from ducts is built straight. The ideal shape of a four-way manhole is rectangular, but with the opposite duct entrances centrally displaced. This provides sufficient space for the training of cables in all cases.

In a number of installations, separate manholes or vaults have been provided for transformers. These manholes are installed, usually, immediately adjacent to one of the main-line manholes, and are connected to negative return feeders. This plan seems to be very desirable when the space in the street will allow construction of this type to be followed. Manholes in which there is likely to be any considerable amount of work

should have a clear head room of at least six feet to provide working space for cable splicers.

In constructing manholes it is desirable to set eye-bolts in the walls at points opposite duct openings, to afford easy attachments for cable-pulling tackles. To facilitate entering the manhole with service connection pipes and to avoid shattering the walls, it is well to insert in the walls, while building, short pieces of pipe leading off in all directions where services are likely to be run.

Duct Arrangement

Conduit lines of a large number of ducts are undesirable and should be avoided wherever possible. More than sixteen cables entering a manhole by one conduit line are difficult to train properly around the walls, and a manhole fire with so many cables may cause great trouble and damage. Where possible, instead of using a large number of ducts, separate lines on parallel streets or on opposite sides of the same street should be installed. In order to avoid more than two cables paralleling along the wall of a manhole on the same elevation, the conduit should be so arranged that not more than four ducts in width enter a manhole. Where the conduit is several ducts wide, it is frequently found advantageous to separate or spread the ducts on entering the hole. The arrangement of ducts, however, is usually determined by the space available in the street, but where conditions will allow, a good form of duct arrangement is as follows:

Two, four and six-duct conduits.....2 ducts wide.
Nine and twelve-duct conduits.....3 ducts wide.
Sixteen, twenty and twenty-four duct-conduits.4 ducts wide.

Manhole Costs

The cost of manholes varies so much with different companies that it is impossible to give data which would be standard for all localities, but Table No. 2 and the curves of Fig. 1 will give an idea of the cost of manhole construction in the Eastern States and the relation between the cost of manholes built of brick and those built of concrete.

ESTIMATED COSTS OF MANHOLES

BRICK CONSTRUCTION

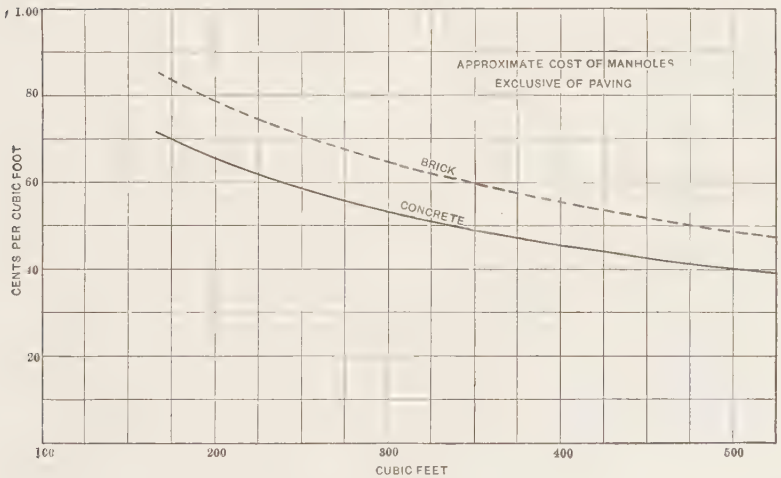
	8′ × 10′ × 6′ 6″	7′ × 9′ × 6′ 6″	6′ × 8′ × 6′ 6″	6′ × 6′ × 6′ 6″	5′ × 7′ × 6′ 6″	4′ × 7′ × 6′
Excavation and removal	$37.00	$34.00	$30.00	$23.00	$21.00	$18.00
Brick in place	120.00	110.00	96.00	86.00	86.00	60.00
Rail	22.00	18.00	15.00	14.00	9.00	9.00
Head and cover	26.00	26.00	26.00	26.00	26.00	26.00
Concrete	13.00	12.00	9.00	7.00	7.00	7.00
Incidentals	20.00	20.00	18.00	15.00	15.00	12.00
Supervision	5.00	5.00	5.00	4.00	4.00	3.00
	$243.00	$225.00	$199.00	$175.00	$168.00	$135.00

MONOLITHIC CONCRETE CONSTRUCTION

	8′ × 10′ × 6′ 6″	7′ × 9′ × 6′ 6″	6′ × 8′ × 6′ 6″	6′ × 6′ × 6′ 6″	5′ × 7′ × 6′ 6″	4′ × 7′ × 6′
Excavation and removal	$37.00	$34.00	$30.00	$23.00	$21.00	$18.00
Concrete	84.00	78.00	63.00	54.00	52.00	48.00
Rail	22.00	18.00	15.00	14.00	9.00	8.00
Head and cover	26.00	26.00	26.00	26.00	26.00	26.00
Frames for concrete	10.00	10.00	10.00	8.00	8.00	7.00
Incidentals	18.00	17.00	14.00	12.00	12.00	10.00
Supervision	5.00	5.00	5.00	4.00	4.00	3.00
	$202.00	$188.00	$163.00	$141.00	$132.00	$120.00

The above estimated costs are exclusive of paving.

TABLE 2



CURVES. FIG 1

Preparing Ducts to Receive Cable

Immediately after installation the ducts should be thoroughly cleaned and freed from obstructions which might injure the cable while it is being drawn in. This is best accomplished by rodding the ducts, which consists in pushing through them wooden rods about 1 inch in diameter and 3 to 4 feet long, provided at each end with coupling devices by which the different sections may be joined. To the end of the last rod is fastened a steel mandrel, which is drawn through with the rods and removes firm obstructions in the ducts, such as set pieces of concrete or cement.

The duct is now ready to receive the cable. If it is to be installed at once, a drawing medium may be provided by attaching to the mandrel a No. 10 or No. 12 B. W. G. galvanized-iron wire of sufficient length, which is pulled through the duct with the mandrel. To this wire is fastened a pulling rope ¾ to 1½ inches in diameter, which may be either a good quality of manila or a flexible steel rope with a hemp core. The ends of the rope should be provided with an "eye" around a steel thimble, fastened to a short piece of chain provided with a swivel at the end. If it is thought necessary to further clean the duct after the mandrel has passed through it, suitable scrapers, gauges, or swabs, fastened to the rope, will remove all loose obstructions.

Before the cable is pulled in, a suitable protector should be placed in the mouth of the duct to prevent injury to the cable sheath by the corners of the duct. These protectors are usually made of leather, although some companies use a brass cable-guard for the purpose. The reel of cable is suspended on a shaft mounted on jacks or wheels on that side of the hole toward which the cable is to be pulled, to permit it to be fed from the top of the reel with a minimum of bending. The cable is fastened to the pulling rope either by means of a universal cable grip or by lacing wire.

Where eye-bolts are set in opposite walls of manholes they may be used to hold the block for the pulling rope, which then passes through the manhole opening to the winch or other apparatus used for the installation of the cable. Short sections of small cable may be readily pulled in by hand, but most large companies, when installing large amounts of cable, use winches run by motors or gasoline engines mounted upon wagons. The

rate of pulling in cable ranges from 20 to 70 feet per minute, depending upon the weight and size of the cable.

When guiding cable into a duct, a small amount of grease should be spread on the cable so as to enable it to slide more easily and lessen the strain. Cushions or protectors of lead, rubber hose, wood or felt should always be left by the drawing-in gang under the cables at the mouth of the duct. The cables should not be left hanging loosely or lying in the bottom of the manhole, but should be placed on racks provided for them.

In removing cable from the ducts, the same equipment is used as for installing, except that a split grip with a double "eye" takes the place of the one with a single "eye" used for drawing in. The grip is attached to the cable close to the mouth of the duct and the cable is pulled out a few feet at a time. If the cable is a short length it may be withdrawn by hand, but if it is too long and heavy to be moved in this manner, a pulling truck may be used with the rope running over sheaves, a method similar to that followed when cable is installed.

Table 3 contains a summary of replies pertaining to manhole construction.

ELECTROLYSIS

As a preliminary to its investigations, the committee sent out to the member companies in all cities having a population above 100,000, according to the last census, the following list of questions:

(1) What regulations are in effect in your city concerning the maximum permissible drop in the railway return circuits, double trolleys, or other conditions having as their object the elimination or reduction of the damage due to electrolysis?

(2) Has there been any litigation directed against the railway company in your city for damage by electrolysis? State briefly the cause of action and the result on the general situation.

(3) Is the railway company owned by the same parties which own or control the lighting company, the gas company or the water supply system?

(4) Has the railway company installed any system for the prevention of electrolysis? If so, describe briefly the system in use.

SUMMARY OF ANSWERS

QUESTION	A	B	C
1. Regulations	None	None	Drop limit 25 volts
2. Litigation	None	None	No
3. Ownership	Yes. Lighting and gas	No	No
4. System of prevention	Copper return along part of track	Copper return	Yes. Insulated retu
5. Co-operation on tests and prevention	Ry., Lighting and City. 1-3 each. Copper by Ry.	Ry. co-operates. No specified basis	Railway assumes en cost
6. Does Ry. Co. pay damages?	None	Unknown	Insulated negative r turns eliminate ca of electrolysis
7. Negotiations in progress	Yes	None	
8. Return copper	Installed old abandoned wire	Copper return—amount not stated	Very large amount i lated cable
9. System of protection	Lead sheath bonded to all railway returns	No means adopted	Insulating joints
10. System of railway company	None	No means adopted	Railway bonds cable
11. Connection to negative bus. Meters and switches	Yes	None	No
12. Grounds on neutral of Edison system	Tied together	A.C. neutral grounded	Neutral grounded on
13. Special precautions to prevent Ry. current on Ed. neutral. Is unbalance noted?	None Slight	No indications	No
14. Max. current on cables. Is carrying capacity reduced?	200 amp. Unknown	No data	8 to 10 amperes
15. Copper in parallel with lead	None	No data	None
16. Bonds between various utilities	All grounded to railway return	No bonds	No
17. Ratio: $\frac{\text{Prevention}}{\text{Damage}}$	Expense shared 1-3 each by Ry., Ltg. Cos. & City. Cost of damage entirely by Ry. Co.	Make no tests	No data
18. Coatings on lead	No answer	No covering	No
19. Chemical action on lead.	None, except electrolysis	No trouble	Action noted. No

STIONS ON ELECTROLYSIS

D	E	F	G
	None	No	None
	None	No	None
ighting and power	Yes. Railway, Elec. and Gas	Yes. Railway and Light	No
return along part ck	Yes. Drainage system partly installed	Yes. Copper return	Copper return bare
does not co-e	Close co-operation	Co-operates closely	Railway entire expense
	No	Same company	No
	No	No	No
pper return. No	Bare copper return	Very considerable; proportion unknown	Extent not stated
ysis surveys three a year. Bonds urn	Cables bonded. Water pipe and rail	Bonding and connections to track return	Parallel with bare copper
makes no effort	No difference	No difference	Railway same scheme
to track return	Yes. No meter. Always closed	Only through ground and track return	Yes. No meter. Closed
grounded at only	Bonded to water pipe and Ry. negative	Ground at station only	Ground and railway negative
	No precautions	No precautions and no data	Insulated neutral. No data
rds	Maximum 1200 amperes. All cables. No data	No data	No data
rge raily sub- n	At no point	At no point	At no point
way underground. only to rail	Yes. Determination by survey	In some cases	Railway negative and water pipes
year. Proportion own	No record	No data	No expense
aseline	No	None	No fibre conduits
ses. No data	No	No record	No

SUMMARY OF ANSWERS

QUESTION	H	I	J
1. Regulations	2½ volts limit. .5 v. per 300 ft.	25 volts limit	None
2. Litigation	No	No	No
3. Ownership	....	.....	.....
4. System of prevention	Drainage at few locations	Insulated neg. ret. feeders over part of city	Return feeder a age
5. Co-operation on tests and prevention	Limited co-operations	Frequent tests	No
6. Does Ry. Co. pay damages?	No	Yes (Gas)	No
7. Negotiations in progress	Yes	No	No
8. Return copper	Vicinity of station bare copper	Return feeders triple braid	Extensive system return feeders
9. System of protection	Drainage	Drainage	Drainage
10. System of railway company	No essential difference	Connects to return	Drainage
11. Connection to negative bus. Meters and switches	Yes, meters and switches where station runs intermittently	No. No. Continuously	No. No. Cont
12. Grounds on neutral of Edison system	Ground plates only	To rails at Ed. Sub. only	No Ed. System
13. Special precautions to prevent Ry. current on Ed. neutral. Is unbalance noted?	Yes No	Yes, see (12) No	No
14. Max. current on cables. Is carrying capacity reduced?	100 amp. No.	No tests No	Amt. known to but not measur
15. Copper in parallel with lead	Yes, for few ft. near substation	No	No
16. Bonds between various utilities	At railway substations only	At railway substations only	No
17. Ratio: Prevention / Damage	80 per cent	No damage	No recent dama
18. Coatings on lead	No	No	No
19. Chemical action on lead	Few cases. Pump log and manure pits	Few cases. Lime	No

ESTIONS ON ELECTROLYSIS

K	L	M	N
prevent damage	None Rigid inspection	None	None
	No	No	None known
and Lt.	Ry. and Lt.	No	No
rn feeders	Return feeders	Only negative return	Only negative returns
terly report	No answer	Not at all	Not at all
(Water)	No answer	No	No
	No answer	No	No
	Yes, bare	Return feeders	Insulated aerial copper
nage	Parallel system	Cables bonded	Cables bonded and insulated from bottom of handholes. Lead sheaths at duct end
e company	Same company	R.R. company has no underground cables	R.R. company has no underground cables
No. Continuously	No. No. Continuously	Yes	No .....
d and neutral tied to y. negative	Neutral tied to railway negative	No three-wire system	No three-wire system
see (12)	Yes No	No three-wire system	No three-wire system
tests	50 amp. No	Not measured No reduction	Inappreciable No reduction
	Where cables are positive	.....	Copper installed
substations only	Where rails are positive	R.R. Co. has no cables Bond to water pipes Connections located where sheaths are positive to water pipes and potential difference large	R.R. Co. has no cables No .....
damage	.....	Main expense for inspection	Damage difficult to estimate and cost of inspection of one manhole, 50 cents
	No	Asbestos tape in manholes but mostly for protection against burnouts	Asbestos tape in manholes, but mostly for protection against burnouts
	Uncertain	.....	None found

SUMMARY OF ANSWERS

QUESTION	O	P	Q
1. Regulations	None known	None	None
2. Litigation	Never tried	Never tried—settled out of court	No
3. Ownership	No	No	No
4. System of prevention	Only negative returns	Only negative returns	Each company bon its own sheaths connects to railw negative bus.
5. Co-operation on tests and prevention	Co-operates but does not share expense	Paid part of expenses of connections to their system	Pays for proportiona of drainage wire f their cable system
6. Does Ry. Co. pay damages?	No	No	No
7. Negotiations in progress	No	No	No
8. Return copper	Bare copper between tracks	Bare copper between tracks	None known
9. System of protection	Cables bonded	Now bonding all cables in every manhole	All cables bonded i every manhole
10. System of railway company	No difference known	R.R. Co. does nothing	.....
11. Connection to negative bus. Meters and switches	Yes No Closed continuously	Yes No, but sometimes measure current Closed continuously	Yes Yes
12. Grounds on neutral of Edison system	No three-wire system	Neutral grounded to junction box castings and water pipes	.....
13. Special precautions to prevent Ry. current on Ed. neutral. Is unbalance noted?	No three-wire system	Have removed neutral ground connections from junction box castings Caused unbalance	No No unbalance not
14. Max. current on cables. Is carrying capacity reduced?	Not measured No reduction	15 amperes or more No reduction	400 amperes No reduction
15. Copper in parallel with lead	Copper installed near railway power house	Copper installed at submarine crossings and under bridges, also near power houses.	.....
16. Bonds between various utilities	.... No	..... No Never to gas pipes, but to water pipes Yes, where sheaths are positive to water pipes, and potential difference large	No No ..... No
17. Ratio: $\frac{\text{Prevention}}{\text{Damage}}$	Inspection and repairs both small	Testing expense involves labor of one man continuously	No data
18. Coatings on lead	No	No	No
19. Chemical action on lead	.....	Chemical action observed. Street drainage showed sulphur contents. Cured by draining manholes	.....

ESTIONS ON ELECTROLYSIS

R	S	T	U
e known	None known	None known	None
threatened	None known	No	No
	No	No	No
y negative returns	Only negative returns	Railway Co. has installed independent system of insulated negative returns	Return feeders
at all	Not at all	Co-operates, but does not share expense	Install additional copper
	No	No	No
	No	No	No
urn feeders	Insulated aerial copper	None except cross-overs and turnouts	Bare return copper
nds lead sheaths to runk neutrals. Uses nsulating joints	Practically no damage	Insulating joints each 800 ft. on high-tension cables and sections grounded. L.T. cables grounded	Drainage
R. Co. has no under-round cables	R.R. Co. has no underground cables	R.R. Co. has system of insulated drainage cables	R.R. has no underground cables
s but sometimes neasure current sed continuously	No	No	Yes. No meter. Continuously
utral grounded and onnected to railway egative bus in one lace	Neutral grounded in manholes and to water pipes	Neutral grounded intentionally at substation only	Ground at station only
	No	No	Insulated neutral. Had unbalance with bare copper neutral
unbalance noted		No unbalance noted	
amperes reduction	Not measured No reduction	26.5 amperes max. No reduction	Current known to be small. No data
ne installed	None installed	None installed	Where cables are more than 1 volt positive
R. Co. has no cables ver to gas pipes or vater pipes	R.R. Co. has no cables No To gas pipes and water pipes on customers' premises No	No No Sometimes to gas pipes in manhole No	Near railway stations
damage discovered	Expense very little. Repairs little or nothing	No data	No recent damage
	No	No	No
ne found	None found	None found	No

SUMMARY OF ANSWERS

QUESTION	V	W	X
1. Regulations	None	None	None
2. Litigation	No	No	No
3. Ownership	No	No	No
4. System of prevention	Return feeders	Drainage	No
5. Co-operation on tests and prevention	Co-operates on testing	Co-operated on installation of drainage system	Limited co-operation
6. Does Ry. Co. pay damages?	No	No	No
7. Negotiations in progress	No	No	No
8. Return copper	Return feeders	Several insulated copper returns	Insulated return
9. System of protection	Bond to rails where positive. Negative boosters in some cases	Drainage	Bond to track return where positive
10. System of railway company	No difference	No difference	R.R. has no undergro
11. Connection to negative bus. Meters and switches	Bond to track return	Yes. No meter. Continuously	No
12. Grounds on neutral of Edison system	Edison neutral grounded at many points	Connect neutral to cable sheath	Bare copper of 3-wi A.C. system is quently grounded
13. Special precautions to prevent Ry. current on Ed. neutral. Is unbalance noted?	Unbalance noted in one case adjacent to poor track construction	No precautions. No data	No
14. Max. current on cables. Is carrying capacity reduced?	200 amperes. No data	No data	No data
15. Copper in parallel with lead	Where cables form a shorter path to railway station than rails	No	None
16. Bonds between various utilities	Yes. Where cables are positive	All bond to some drainage wires	Where cables are pos
17. Ratio: $\frac{\text{Prevention}}{\text{Damage}}$	No data	No data	40 per cent
18. Coatings on lead	No	No	No
19. Chemical action on lead	No	No	Two cases near drug panies, due to bro containers

JESTIONS ON ELECTROLYSIS

Y	Z	ZZ
e	None	Double trolleys have eliminated all damage by electrolysis
	No	
Lt. and Gas	No	
	Drainage	
e company	Close co-operation	
material damage	No answer	
	No	
e	Insulated return where necessary	
d covered cables in ore conduit. Jute vering on lead in tile nduit. Manholes well ained. No bonds	Bond to track return where positive	
has no underground	R.R. has no underground	
transmission lines ly. No meter. Con- nuously	Bonds to track return near station	
tral not grounded	Bond neutral of A.C. system to water mains	
12	None found	
wn to be small, but ot measured	Not known	
e	No	
e	Near railway stations only	
ense is small	Not known	
covering impreg- egnated with asphalt, d tile conduits	No	
	No	

(5) To what extent has the railway company co-operated in investigations and in sharing the expense of installation of additional copper for the prevention of damage to the cables of your company?

(6) Has the railway company paid any portion of the expense of repairs to cables or pipes damaged by electrolysis?

(7) Are there now in progress any discussions or negotiations which would alter the situation?

(8) To what extent has the railway company installed copper to reinforce the rails for carrying return current? Does the railway company use bare or insulated cables for this purpose?

(9) Describe briefly the methods used by your company to prevent damage to its cables by electrolysis.

(10) Describe briefly the principal points of difference between your scheme and that used by the railway company for the protection of its own cables.

(11) Have you any direct connections between the lead sheaths of your cables and the negative bus of the railway stations? Is there a meter on this connection? Is this circuit closed continuously, or is it open when the station shuts down?

(12) To what extent do you make connections between the neutral of your three-wire Edison system and the ground or the railway negative bus?

(13) Have you taken any special precautions to prevent the neutral of your Edison three-wire system from carrying railway return current? Is the amount of current carried by your neutral in this manner sufficient to cause any unbalance on your Edison system?

(14) What is the maximum amount of current that you have found on the lead sheaths of your cables? To what extent does this current reduce the carrying capacity of your cables?

(15) At what point have you found it necessary to install additional copper in parallel with the lead sheaths of your cables?

(16) Are there any bonds between your cables and those of the railway company, telephone company, gas or water pipes, or the rails of the railway company? How is the location for such connections determined?

(17) What is the approximate ratio between your expense for inspection and tests for the purpose of preventing damage by electrolysis and the cost of repairs due to electrolysis?

(18) Have you used any covering or coating on the lead sheaths of your cables to prevent damage by electrolysis? Describe its nature, method of application and results obtained.

(19) Have you had any trouble from chemical action on the lead sheaths of your cables? State briefly the nature and amount.

Answers were received from about thirty companies. After excluding several which were incomplete, a summary was prepared, as shown in Table 4, of the answers from the operating companies in the following cities:

Boston	Fall River	Rochester
Albany	Newark	St. Louis
Baltimore	New Orleans	Portland
Chicago	Minneapolis	Spokane
Cambridgeport	Lowell	Worcester
Milwaukee	New Haven	Syracuse
Cincinnati	New York	Toledo
Memphis	San Francisco	Grand Rapids
Denver	Omaha	Birmingham
Detroit	Providence	

It is noted that there are regulations which limit the maximum drop in the track return in only three of these cities. An examination of the other answers also indicates that in general the return system of electric railway companies is most expensive where the regulations are most severe, or where the railroad company must pay for repairing the damage caused by electrolysis.

The fact that there is no litigation in progress at the present time indicates that this subject is not a very live one in those cities whose answers are included in the appended summary. Electrolysis, however, is a trouble which is slow and insidious, and its destructive action on the lead sheaths of cables generally occurs over a considerable area. Experience in some cities has demonstrated that where this subject is neglected considerable damage has been done to the lead sheaths before burn-outs actually occur from this cause, and that even if the remedial steps are taken immediately after the first burn-out there may be a long series of such cases before troubles from this cause are finally eliminated.

The answers regarding the systems of protection which have been installed indicate that the Parallel System is the most popular, with the Drainage System a close second. The answers from some cities indicate that additional copper for protective purposes is being installed in a rather haphazard manner and without a comprehensive study of the entire situation and a definite plan of procedure.

There appears to be a considerable difference in the practise of the various companies in bonding their cables to the gas and water pipes and the telephone cables. In one city the underground metallic structures of all utilities are connected to the same drainage cables. In other cities similar connections are made to the water pipes but the gas pipes are carefully avoided. In most large cities there are a large number of water heaters using gas, in which the water and the gas pipes are metallically connected at the heaters. Where such installations exist there would appear to be no objection to connecting the gas and the water mains electrically in the street.

In order to reduce the maximum drop in the rails, and in this manner reduce the chances of damage by electrolysis, one railway company has extended insulated negative return feeders for some distance from the station and has omitted the connection to the rails near the station. This results in the rails being at a fairly uniform potential over the area included by these negative feeders. A system of this kind is of the greatest advantage where the railway power station is in the downtown district; that is, in the location where a positive area would include the maximum amount of pipes and cables.

Several companies bond the neutral of their three-wire system to the sheaths of their lead-covered cables and to the railway return circuit at frequent intervals. This puts not only their lead sheaths, but also their neutral in parallel with the railway return and must eventually result in a drop of potential along the neutral towards the railway power station, causing an unbalance in the three-wire system. Several companies have had this experience, and in order to eliminate the difficulty, have been compelled to remove the connections between the neutral and the railway return circuit.

The answers indicate that in cities where the subject of electrolysis has received attention from the lighting companies

these companies have taken the matter up individually with the railway companies and that protective measures for the benefit of the lighting companies have been applied without reference to any effect which such measures might have on the underground metallic structures of other utilities. This is a narrow policy for the treatment of this subject. All underground metallic structures are liable to damage from electrolysis, and if only one is protected the injurious action on the others will be increased. All of these structures should therefore be treated as a single system and be included in one comprehensive scheme of protection; otherwise the protection will be incomplete, and in the end more expensive.

The destruction of underground metallic structures by electrolysis is a matter of concern with many electric light companies operating underground systems and with other public utility companies as well, but because of the expense of reconstructing a railway system so as to prevent the escape into the ground of return currents, and because of a lack of co-operation among the interests involved, the destruction often continues year after year without even a friendly conference among the interested parties to see if some comprehensive remedy, with an equitable division of expense, might not be agreed upon.

The committee, therefore, offers the following with particular reference to the protection of the lead sheathing of cables in the hope that it may lead to a course of action which will promptly stop the greater part of the destruction and lead eventually to a permanent and complete remedy.

In discussing this problem, it may as well be stated at the outset that the railways are the offenders and upon them should fall the major part of the expense of preventing the destruction of the property of the other utility companies, but as railways are sometimes not in a position, and often not in a mood, to stand the entire cost of the best—which usually means the most expensive—alterations for the relief of other companies, and as the less expensive method requires the consent and co-operation of all sub-surface utilities, a willingness to co-operate and to contribute on the part of the other companies may lead to an effective and relatively inexpensive solution of the whole problem.

The electrolytic corrosion of metallic structures in streets is caused by return railway currents leaving those structures

through moist earth, usually in the vicinity of railway power-houses or substations. The remedy, therefore, lies in preventing return currents from "leaving those structures through moist earth," and for this prevention, various means have been adopted, but before any other means are applied the bonding of the tracks should be made as perfect as possible, as no remedial measure can be wholly effective with imperfect rail bonding. The following are the important remedial measures which have been used:

(a) Systems in which the entire expense is borne by the railway company:

(1) The Double Trolley System.
(2) The Insulated Negative Return Feeder System.
(3) The Three-Wire Trolley System, with the rails as a neutral conductor.

(b) Systems which require that the entire expense should be borne by the lighting company:

(4) The Parallel Circuit System.
(5) The Insulating Joint System.
(6) Waterproof Conduits.

(c) Systems which require the co-operation of both companies and which call for a division of the expense:

(7) The Drainage System.

(1) *The Double Trolley System.* This system absolutely prevents electrolysis, because the rails are not used as a portion of the return circuit. The positive and negative conductors and feeders are duplicates, so that the cost approximates double that of a single trolley system. This system is required by municipal regulations or court decisions in several American cities, notably Washington, Cincinnati, and the surface lines of the Borough of Manhattan, New York.

(2) *The Insulated Negative Return Feeder System.* In this system the tracks are drained of current at radially disposed points about the power-station, by means of insulated negative return feeder cables. The negative bus-bar is not connected to the tracks nor to ground in the vicinity of the power-station. Pressures as nearly equal as are required may be maintained at the track end of the return feeders by the use of rheostats on short feeders and boosters on long ones, or by greatly increasing

the amount of copper in long feeders without using boosters and rheostats. The cost of the system increases very rapidly as the permissible maximum variation between various portions of the track decreases. The English Board of Trade regulations fix a maximum variation between portions of the track at 7 volts, and the same, or a lower maximum is found in the regulations in Moscow, Vienna, Paris and other European cities. In a few American cities insulated negative return feeders have been installed in a portion of the city so as to secure an equi-potential condition of the track in the area where the amount of underground cables or pipe subject to damage is the greatest.

(3) *The Three-Wire System.* This requires that the generators in the station must be divided and half connected to the positive trolley and half to the negative trolley. This system has been tried in a few American cities, but on account of difficulties in maintaining a balance, the increased complications at the switchboard and the difficulty of maintaining the cross-overs between tracks, has been abandoned.

(4) *The Parallel Circuit System.* In this system the cables are bonded together and to the rails at as many points in the positive districts as possible. This puts the lead sheaths of the cables in parallel with the rails as a return conductor for the railway current. In case of a broken rail joint the lead sheaths may be overloaded. If a drainage system is installed for the protection of gas and water pipes, these pipes would probably be at a lower potential than the lead-covered cables, thus rendering the latter subject to electrolysis. This system has met with a fair degree of success where carefully installed and inspected.

(5) *The Insulating Joint System.* As its name indicates, this system requires that the cable sheaths be broken by insulating joints at frequent intervals. If the insulating joints are sufficiently numerous and each of the sections of cable are properly grounded, this system appears to give good results. An interesting paper on this system as applied to gas pipes was read before the 1911 convention of the American Gas Institute in St. Louis. There appears to be some difficulty in applying this system of protection to an extensive system of underground cables, and especially where the number of cables per manhole is large and the manholes are crowded.

(6) *The Waterproof Conduit System* has been tried in a few cities, but is virtually impossible to maintain under the conditions which exist in American cities. Not only must the conduits be waterproof throughout their length, but the manholes must be waterproof as well. In some cities a waterproof type of conduit, with carefully made joints, has been installed with some success for the purpose of preventing electrolysis in locations where the cables were particularly subject to damage from this cause. The system appears to be useful as a local remedy rather than as a system to be used throughout an entire city.

(7) *The Drainage System.* In this system the cables are bonded in manholes at frequent intervals, preferably in every manhole and are connected to negative return feeders. Additional copper is installed where necessary so as to afford a continuous path to the railway negative bus. Additional copper may also be necessary in parallel with the lead sheaths of the cables in the immediate vicinity of the substation. A meter should be installed on the connection to the negative bus, and if the station shuts down for a portion of the day there should be a switch in the connection to the negative bus, and the circuit should be opened when the station is not in operation. A drainage system properly installed will maintain the lead-covered cables throughout their length at a potential lower than that of the rails, gas pipes and water pipes. Drainage systems which have been installed under average conditions and connected to all underground pipes and cables, carry between 10 per cent and 15 per cent of the total amount of current returning to the station. To prevent overloading of the gas and water pipes in the vicinity of the station, it is frequently necessary that the drainage cables for these pipes be insulated and extended for a distance of 2000 feet or more from the station.

Some calculations made in one large city recently indicated that the total cost of additional feeder copper for the purpose of reducing the maximum drop in the tracks from 25 volts to such a point that no damage to the pipes and cables by electrolysis would occur, that is approximately 10 volts, would be about ten times the cost of installing a drainage system for all underground pipes and cables at all railway stations throughout the city. The drainage system has been used by the Bell Telephone Companies

throughout the country for the protection of their cables for many years. The city authorities have also compelled the installation of drainage systems in a few cases where the water system is owned by the city and the pipes were being seriously damaged. The drainage system is not only simpler, but very much cheaper to install than the insulating joint method on a system of cables or pipes which are already in place in the ground.

In those cities where the electric light companies are suffering from damage by electrolysis, it is probable that the underground systems of the telephone, gas and water companies are also suffering in a similar manner. It is therefore suggested that where these conditions exist the lighting companies co-operate with these utilities in a friendly conference with the railway company with the object of ascertaining if the installation of an insulated negative return system can be immediately brought about, or if not, if the installation of a drainage system would not afford, at least as an intermediate step, a measure of relief warranting all interests in sharing in some proportion in the cost.

HIGH-TENSION CABLE DATA AND SPECIFICATIONS

The following data on high-tension cable and conduit have been compiled from the detailed reports of central-station companies operating in seventeen large cities and localities. It deals with mileage, size and operating voltage of cable in service, thickness of insulation and burn-outs, carrying capacity of cable and methods of determining it. It also considers kind, size and heat-dissipating qualities of conduit, as well as thickness of lead sheath and the effect of a small percentage of tin in same.

All the collected data relative to the physical properties of cables is contained in Table 5. These cables are working at pressures varying from 5500 to 25,000 volts and comprise a total of 1912 miles, made up of various sizes as follows: 1/0 or smaller, 170 miles; 2/0, 175 miles; 3/0, 142 miles; 4/0, 486 miles; 250,000 cm., 874 miles; 300,000 cm., 15 miles, and 350,000 cm., 22 miles, while 50 miles are not classified. All the cable except 69 miles is paper insulated and impregnated. Two companies specify resin and resin oil as the impregnating compound. Thickness of insulation in general conforms to manufacturer's specifications, except where expediency dependent on local con-

ditions permits deviation, and then mostly in the direction of greater safety.

The conduit includes fibre, clay, cement lined, vitrified tile, terra cotta, single and multiple, and round and square ducts ranging between 3 in. and 4 in. of largest diameter. The usual thickness of the lead sheath is ⅛ in. and in no case does it go below 3/32 in., except on single-conductor cable. Several companies specify a small percentage of tin in the lead sheath.

Opinions regarding the highest safe carrying capacity of cables conform very closely to the Underwriter's table for rubber-covered wire, but five of the larger companies assume overload capacities of 10-20 per cent in excess of normal carrying capacity for periods up to two hours. One company limits the capacity of its cable by the allowable drop, while another company considers 240 amperes a full load for a 300,000-cm. cable. Several companies reduce the current density with increased size of cable.

Four companies have made service tests to determine the safe carrying capacity, three by observing external temperatures, one by observing external temperatures and also by measuring internal temperatures by resistance measurements on conductor.

These latter tests indicated that the temperature rise on a conductor of a 4/0 cable, after an 8-hour run at 200 amperes, does not exceed 38 degrees C. above manhole temperature, leading to the conclusion that this load is well within the safe carrying capacity.

But one company makes allowance in its table of safe carrying capacity for a larger number of loaded cables in one conduit. While it considers 195 amperes a safe load for a single 3/0 cable, it reduces this carrying capacity to 105 amperes if ten cables are in one conduit line. Intermediate values are interpolated between these extremes from number of cables in conduit. These values were arrived at through measurement of temperatures obtained in ducts adjacent to cable in actual service. Two companies expressed willingness to avail themselves of the advantages of low external temperature should occasion arise to load the cables extra heavily.

In regard to the heat-dissipating qualities of different kinds of conduit, no data was obtainable. One of the companies that took duct-temperature readings had only one kind of conduit installed, namely, vitrified duct. This company, as a result of

these readings, decided to make allowances for a given number of loaded cables in one conduit line, and as a result limited the carrying capacity of the 3/0 cable to 105 amperes when 10 loaded cables were in the same line. These tests were made during the summer under extremely unfavorable conditions.

The other company which took duct-temperature readings aimed only at the cable temperatures to determine the safe carrying capacity of the cable. Comparative conduit observations were not taken, nor was the kind of conduit specified.

An attempt was made to obtain reliable data in regard to the number of burn-outs per 100 miles of cable per year in the systems of the various operating companies, excluding all cases of trouble due to electrolysis, short bends, or external injury to the cable sheath. The answers, although not so complete as they might have been, are tabulated in Table 5.

Concerning the influence of the seasons upon the number of burn-outs, three companies report that the greatest number occur in summer; two companies attribute it to the high temperature and one company suggests keeping the conductor temperature at below 160 degrees F. The third states that tests made indicate that the puncture resistance of paper-insulated cable does not diminish up to 100 degrees C.; five other companies, however, have not noticed any perceptible influence of external temperature upon the number of burn-outs.

Cracks in the lead sheath were observed by two companies, and one attributed it to a poor mixture of tin and lead, the other to crystallization due to poor workmanship in some cases and in others to wear in the lead sheath caused by the rubbing of successive layers on reels during transportation. One of these companies uses tin in lead sheath, the other lead only.

In regard to the values of tin in lead sheath opinions are divided. Two companies think a small percentage of tin desirable; one has found it good protection against electrolysis, the other recommends 1 per cent. Five other companies have either had no experience in the matter or depend upon the manufacturer's advice, while two think that tin is not desirable; one of these two companies has had tin up to a recent date, but of late has ordered cable with lead sheaths free from tin.

One company was limited by 3¼-in. round duct in selecting the size of 20,000-volt cable, but did not install a larger duct.

Two other companies were limited by 3-in. ducts in installing the desirable cable; one of these overcame the difficulty by decreasing the size of the insulation, but both plan installing larger ducts in future conduit installations. One company, though not limited, has also decided to install larger ducts. The tendency seems to be to install larger ducts as the increased load density warrants the installation of larger cable. But one company installed a larger duct than normal to permit the installation of a larger size cable.

The practise and opinion of most companies concerning the removal of cables from one duct to another is conservative. While several companies think it safe to pull out cable from one duct and install it in another, most of them when they have occasion to do this use the reinstalled cable for lower voltages. One company has reinstalled 13,200-volt cable and has had good results in operating it at that voltage.

Concerning high-tension cable specifications, but three companies submitted copies, two others used manufacturer's standard specifications, but nearly all make factory or after-installation tests varying in severity and duration. One company simply requires the cable company to guarantee all cable against breakdowns for five years, and is satisfied that defects in the workmanship of a cable ought to appear in that period. Another company makes a similar agreement for one year. The other companies specify only thickness of insulation and size of copper.

Concerning the factory tests, they differ materially. One company insists on a factory test-pressure of 40,000 volts for 13,200-volt cable for 30 minutes, and on a 50,000-volt test for 25,000-volt cable for the same period. Another company tests 23,000-volt cable at 62,500 volts between conductors and 52,500 volts between copper and lead sheath for 5 minutes, while four other companies make factory tests of 200-275 per cent of normal working pressure for 1 min., 1 min., 20 min. and 30 min. periods on cable of the following corresponding working pressures: 9000, 12,000 and 20,000-volts for one company; 11,000, 13,500 and 5500 volts for the others.

Two companies insist on an insulation resistance test of 125 megohms per mile at 60 degrees F. after one minute's electrification, using a battery of 100 volts. Another prescribes a resistance test of 250 megohms per mile before accepting the

cable after one year's service, while a third company simply specifies that any tests desired by its engineers must be made to convince them that the cable conforms to the guarantees.

The Committee has also looked into European cable practise and finds the prevailing European tendency to be to give the manufacturer unlimited latitude in the selection and thickness of insulating material as long as the cable withstands the prescribed tests. There also seems to be considerable difference of opinion concerning the value of a high insulation resistance. Of special service in this respect was a set of specifications prepared by Messrs. Merz and McClellan, of London.

Based on the information gathered, the committee has prepared a set of specifications intended to point out what may be required from cable manufacturers. No attempt has been made to prescribe methods of manufacture nor insulating materials to be used; this, it is thought, being more properly the manufacturer's problem. The question of tin in the lead sheath is left to the different operating companies, as considerable difference of opinion concerning the merits of an alloyed sheath, as well as the increased cost of manufacture incidental to it, prevents the committee from reaching a definite conclusion regarding it. The tests prescribed, however, are thought not to be any more severe than high-grade cable should be able to withstand. It is also thought desirable to induce cable manufacturers to produce a higher grade of insulation than is now commonly used, something to equal that used in the manufacture of European cables, where considerably lower insulation is used for corresponding voltages. This is of considerable importance to operating companies in so far as with such insulation the present conduit systems would permit the installation of cables with larger copper which at any time may be required by a steadily increasing load density in all growing communities.

STANDARD FORM PAPER-INSULATED HIGH-TENSION CABLE SPECIFICATIONS

Condition of Service

The cable is to be used as a part of a three-phase, ...-cycle, delta/star connected underground transmission system, the normal working voltage of which is ..... volts between phases,

the term voltage defined by American Institute of Electrical Engineers' standardization rules.

General

The cable shall be composed of three separately insulated stranded copper conductors, laid together and covered with a suitable sheath. All labor and material employed in the manufacture and installation shall be of the best quality, appropriate for the purpose intended, and shall conform to the following specifications:

The cable covered by these specifications shall be guaranteed by the manufacturer to be free from defects in workmanship and material, and the manufacturer shall replace, without cost to the purchaser, any cable which shall develop faults within a period of ..... years from date of installation, except in cases where it can be clearly shown that the fault resulted from external causes, such as mechanical injury, electrolysis or lightning.

Conductors

The conductivity of each conductor must be not less than 98 per cent of the annealed copper, as defined by the American Institute of Electrical Engineers' standardization rules. The conductors are to be stranded and of wires sufficiently small to insure the required flexibility of the cable. The area of each conductor shall be ..... circular mils and shall be taken to be the sum of the areas of the several wires forming the stranded conductor, measured at right angle to each wire.

Insulating Material and Covering

The insulating material is to be of the best manila paper cut in strips, spirally and tightly wound around each conductor. After insulation the three conductors shall be laid together with a uniform twist, having a pitch of ..... times (or not exceeding twenty-five times) the diameter of one conductor measured over the insulation. Interstices are to be filled with jute so that the whole will form a true cylinder, over which shall be applied an insulating jacket of paper of the same kind and quality as that used around the conductors. During this process the paper and jute shall be thoroughly impregnated with a suitable insulating compound of specific low inductive capacity, as low as the best compound used for high-tension cable insulating purposes. The

insulated cable shall then be covered with a sheath composed of freshly mined, commercially pure lead (covered with a coating of tin or alloyed with ..... per cent of tin). The sheath shall be free from blow-holes, cracks, scales or imperfections of any kind, and shall be tightly and evenly applied with a uniform thickness of ../32 of an inch. External diameter of finished cable shall not exceed ..... inches.

Tests

The following electrical tests shall be made by the manufacturer at his works and without expense to the purchaser, the manufacturer supplying all necessary apparatus, and the purchaser to have the privilege to be represented when these tests are conducted. The manufacturer shall furnish the purchaser with copies of data sheets showing behavior of cable during these tests.

(a) *Voltage Test.* Each length of cable is to be tested with alternating current, having a frequency preferably the same as that of the system of which the cable is to be a part. The test voltage is to be applied between all three conductors and between conductors and lead sheath at a temperature of 150 degrees F. and after cable has been immersed in water for 24 hours. The apparatus supplying the energy for the voltage test must have a kva capacity at least four times the kva absorbed by the length under test, and in any event must be of not less than 25-kva capacity. The time of application of the test and test pressure shall be:

> Five minutes at a voltage having a peak value two and one-half times that of the normal working pressure as determined by spark-gap in accordance with the A. I. E. E. standardization rules.

(b) *Insulation Resistance Test.* (1) An insulation resistance test shall be made immediately before immersion, twelve hours after immersion, and immediately before and after the voltage test. (2) The measurement shall be made with a direct-current voltage of not less than 100 volts, the reading to be taken after one minute's electrification, and shall show no appreciable decrease in the value of the insulation resistance between any two successive measurements.

(c) *Breakdown Test.* Samples from 10 to 25 feet long and selected by the purchaser at random from any cable lengths shall

not break down under five times the working pressure applied for five minutes between all three conductors and between conductors and lead sheath, after samples with ends sealed have remained at a temperature of 150 degrees F. for 100 hours in straight, single lengths with axes inclined 15 degrees to the horizontal.

(d) *Bending Test.* A sample from any length of cable shall be bent around a cylinder having a diameter equal to twelve times the outside diameter of the cable over the lead sheath, and then be straightened out. It shall then be bent in the opposite direction around the cylinder and straightened out. This operation shall be performed twice in succession, after which the cable shall be capable of withstanding a voltage test two and a half times working pressure applied for a period of five minutes between the conductors and between the conductors and the lead sheath, and shall show no signs of cracking or other mechanical or electrical injury when dissected.

Test After Installation

The cable shall be capable of withstanding twice normal working pressure applied between all three conductors and between conductors and lead sheath for a period of thirty minutes, after being drawn into the ducts and jointed. An insulation resistance test shall be made immediately before and after the breakdown test, using the method specified under (b-2) above, and the insulation resistance shall not be materially reduced as a result of this test.

Respectfully submitted,

Committee

W. L. Abbott, *Chairman*
Geo. W. Cato
P. Torchio
S. J. Lisberger
H. B. Alverson
Burton French
E. B. Meyer
S. B. Way
A. S. Loizeaux

DISCUSSION

Mr. L. L. Elden, Boston: This most excellent report on underground construction is entitled to serious consideration, dealing as it does with the most costly features of transmission and distribution systems. The numerous problems developed in the construction and operation of underground systems in different localities make it the more important that all the knowledge available be placed in suitable form for the information of the members of the Association.

Naturally, when placing cables underground it is hoped that freedom from interruptions of service may be attained, and except under extraordinary conditions such results may be expected if the work is carried out in an approved manner. Conduit construction should, so far as possible, include all known protective features in its design to forestall the development of troubles from electrolysis, mechanical injuries, damage to lead sheaths during installation and the spread of burnouts to cables other than the one in which a failure originates. In choosing a type of duct attention is directed to the excellent results obtained with the insulated forms of duct, such as fibre or wood. Aside from the lower first cost, the protection afforded the cable sheaths from mechanical injury during installation is of prime importance, as is also the prevention of troubles from electrolysis.

Manhole construction deserves the most careful consideration as regards the spacing and arrangement of ducts entering and leaving the hole. While in earlier work large conduits were frequently constructed, later experience emphasizes the recommendations of the Committee as to the desirability of limiting the number of ducts in any one group entering a manhole to 12 or 16, with a preference for the smaller number in city distribution, particularly where cables of large size and heavy capacities are to be cared for. With groups of ducts of moderate sizes, it is possible to spread the ducts when entering manholes, to facilitate the easy racking and protection of cables, the elimination of short bends and the construction of suitable vertical and horizontal barriers between ducts as they enter and leave.

Manholes should, wherever possible, be automatically drained of accumulations of surface or drainage water, either through sewer connections or other special means provided for

the purpose. Attempts to secure waterproof construction in conduit work have not been altogether successful and in general may be considered an unnecessary precaution.

The installation of transformers in main-line manholes is open to question as to the desirability of that form of construction, it being contended that better conditions will result from the use of entirely separate transformer manholes, suitably arranged with two-part covers for the installation of transformers of any reasonable capacities.

Ventilation of manholes and conduits is naturally inefficient, unless special means are employed to increase the natural circulation of air within the conduit. Conduits frequently suffer from explosions of gas accumulations in both manholes and ducts, and while various means have been employed to prevent such accidents, it is apparent that real relief lies in efficient ventilation. Perforated manhole covers afford some relief for this evil, and while not always providing sufficient ventilation to carry off accumulations of gas, it is noted that where explosions do occur, their violence and the disturbance of the earth is much less severe than where either double or unperforated covers are used.

Reference is made in the report to the use of brass tags for the identification of cables. It has been the speaker's experience that in general the life of brass tags is limited to about two years in such locations as are wet or affected by electrolysis. Experiments with other materials, such as lead, aluminum and fibre have been similarly unsatisfactory, and any suggestions which may be offered regarding more suitable materials for tags would be gratefully received.

The bonding of cables should receive careful attention in all cable systems from two points of view. First, bonds between cables themselves in all manholes, and, second, bonds between cable sheaths and ground, and to the structures of other utilities, such as gas and water mains and the return systems of street railways. In the first case in alternating-current distribution using single-conductor cables, the disposition of sheath currents should be given serious consideration to prevent destruction of cable sheaths at points of contact with each other, and to prevent sparking between cables in manholes, where conditions may at times be favorable for explosions to occur through the ignition of gas.

Transmission cables in systems operating with a grounded neutral should be heavily bonded together at frequent intervals, to afford a path of as low resistance as possible for fault currents developed upon the occasion of cable failures. These currents run up to abnormal values in systems of large capacities and in most cases it is preferable that the sheaths of such cables be not bonded to other cables of the same system.

The Committee, in its report, has referred briefly to several of the methods employed for the elimination of electrolytic troubles, in which bonding between cable sheaths and railway returns has been suggested under different conditions. That success can be attained in certain localities where reasonably dry soil conditions obtain is a fact, and the contrary is true in abnormally wet locations where cables may be immersed a majority of the time. This is particularly true in conduits in the seaboard cities where the high conductivity of the earth moisture, due to salt impregnation, makes the diversion of foreign currents exceedingly difficult in wet locations. Among the various methods referred to for the protection of cables the use of insulated joints has been suggested, but after an extended trial, the speaker is of the opinion that such construction can be successful only in conduits which are reasonably dry and where the cable is installed in fibre or some other form of insulated conduit, with manhole construction permitting the introduction of protective insulating materials to keep the cables from contact with shelves or cable supports.

Further study of this subject of bonding or otherwise protecting cable sheaths from electrolysis is of great importance, and future committees on this work will undoubtedly add to our knowledge on the subject. At all events, those companies making new underground installations should give all these matters careful thought before proceeding with construction which will be subject to possible trouble from this source.

At one point the Committee suggested that in a certain case a potential of 10 volts between sheath and railway return would be satisfactory in preventing electrolytic action, and it would be of interest to know if there were any other special conditions present in the case which would prevent action at such a high voltage. Severe electrolytic action has been noted on cable sheaths under ordinary conditions where the potential has not exceeded two volts.

It is to be hoped that future committees dealing with underground construction will go into detail regarding desirable and undesirable methods employed in handling and installing cables, as it is evident that the employees of operating companies who regularly carry on such work are usually not properly instructed on many of the vital points. Extended observation of this work indicates that in numerous cases instructions which direct workmen what not to do would be fully as valuable as those which attempt to instruct in what must be done.

Emphasis should be given to arranging emergency connections between the several parts of alternating-current distributing circuits, in order to prevent extended service interruptions when carrying on construction, or when failures of underground equipment occur. Overhead construction on moderate voltage systems has always been carried on with the lines alive, but in underground work this is not always possible or advisable, and therefore sectionalizing arrangements are a necessity, if high-class service is to be rendered.

This phase of underground construction is not standardized and it will be noted that prevailing practise includes in some cases the use of oil-immersed fuses or oil switches for the protection of transformers or for sectionalizing lines, while in others the entire absence of any devices of such character is observed. The Committee can render valuable assistance to the business by indicating approved methods in this branch of construction.

In dealing with the question of cable specifications the report refers to the carrying capacities of cables and the wide difference of opinion among the various engineers on this subject. So little information is available regarding the heating of cables when in actual service under changing load conditions, that a careful study of this subject by the Association would be well warranted. Such a study should involve determination of the heat-dissipating values of the different sizes of conduits and different types of ducts, under varying conditions of load and grouping of cables of different types. This data can be obtained from existing systems under conditions which will permit definite recommendations to be made for our future guidance; and would undoubtedly result in indicating the possibility of carrying increased loads on existing cables in many cases where the maximum loads are of short duration. Observation of cable temperatures in systems

where peak loads average less than one hour has made it evident that the carrying capacities of certain cables may be increased 10 to 20 per cent above the manufacturer's ratings without reaching excessive temperatures.

When referring to allowable cable temperatures the speaker suggests that the usual practise of specifying a certain number of degrees rise is an undesirable method to employ. Specifications covering maximum allowable cable temperatures are better practise, in that they allow advantage to be taken of low winter temperatures to obtain the maximum use of cables during such periods, which ordinarily correspond to peak-load periods.

In discussing high-tension cable specifications the report notes the superior results obtained by foreign cable manufacturers in the production of paper-insulated cable. Operating practise seems to bear out this contention, and it is gratifying to note that the Committee, in its recommendations for a standard specification for paper-insulated, high-tension cables, has included many features which have been considered important in foreign practises in preparing cable specifications.

While the proposed form as submitted covers the main points to be considered, the speaker, after an extended study of the subject, suggests that an improved product would be secured if additions to and changes in the wording of the specifications were made in the following items:

Insulating Material

Quality of Manila paper should be more clearly defined to prevent use of inferior grades of paper. Thickness of insulation specified should be designated as the minimum thickness of insulation at any point in the cable.

Impregnating materials should be specified as to fluidity and manner of application to fill all voids.

Bending Tests

Increase the number of bending tests from two to three.

Testing

Define more clearly the manner of making pressure tests and provide that partial tests which may be successful shall not be considered as the final acceptance test. A full and complete

test after all faults have been eliminated should be considered as the only acceptance test.

Provide for prompt replacement by the manufacturer of joints or sections of cable which may fail under test.

Insist upon a guarantee period of not less than five years, eliminating from the manufacturer's responsibility failures due to external injury, electrolysis, etc.

The above suggestions cover some of the principal points in which changes may be made with profit, but above all, make the specified tests, for experience proves that to be the surest method to employ, to actually obtain a high-class installation capable of successfully meeting operating conditions. The application of these tests will do more to eliminate future cable failures than will the expenditure of any similar amount of effort elsewhere in a transmission or distribution system.

Reciting the results of cable testing in one large system dur ing the past year and a half, it may be stated that with one exception no single new transmission cable successfully withstood the initial pressure test of twice the working pressure. Tests on cables already in service were still more unsatisfactory, many failures occurring in very short intervals, at slightly in excess of working pressure, one cable in particular having failed in 27 successive tests, while others have failed in like proportion. Upon completion of these tests on the transmission system referred to, it is expected that cable failures will in the future be reduced to a minimum.

With the knowledge that potential rises of approximately 100 per cent occur in most systems from time to time, the importance of carrying out this provision of the specifications may be appreciated.

The need of suitable records covering underground systems becomes more and more emphasized as a system grows in importance, and the creation of such records in the initial stage of the construction of such systems is of primary importance in simplifying later work. A record system occupies an important place in the operation of a system both for the information it affords the cable men in carrying out their work and for preventing personal injuries through attempting to work on the wrong cables.

A summary of the precautionary measures employed by different companies for the protection of their underground men,

including methods of phasing high-tension cables, identification of live cables, testing for faults, etc., would be of more than passing interest. In this connection the speaker submits for the consideration of the Committee a simple method of phasing high-tension cables during repairs, which by employing low-tension current prevents any possibility of injury to the workmen and at the same time avoids the necessity of making up temporary joints or using high-potential phasing apparatus for such purposes.

It is to be hoped that the work of this Committee will go on and that finally all information of this character concerning approved methods of both overhead and underground construction will be collated and issued as a separate reference volume not only for the information of our members, but to serve as a guide for those municipal officials whose duty it is to supervise and approve our construction.

I may add that I have a copy of the specifications used by our own company which cover in great detail many of the points that have been discovered to be absolutely necessary in installing high-tension cables, and this I shall be glad to submit to anybody wanting such information. [Applause.]

The Chairman: Is there to be any further discussion on this most interesting Report? If not, I would like to call attention to the matter of electrolysis. That is a subject which has, of course, been up for a great many years, but now has an added interest under a decision rendered recently in the Peoria Water Case, after 14 years of litigation. The decision was adverse to the railway company. I would like to illustrate the importance of the subject by one case in the middle west, in which various interests were rather slow in getting together. They did get together finally, made a comprehensive study of the matter and determined that a drainage system at moderate cost would rectify 90 or 95 per cent of the trouble. In the interim, however, some ambitious city authorities prepared an ordinance that is pending, which is very stringent, limiting the return drop per thousand feet of conductor to one volt, and further providing that the maximum drop between the return conductor and ground should not exceed 12 volts. That drainage system could have been installed, and probably will be installed, at a cost of about $300,000. If the various railroad companies work together as

they would if merged or consolidated, and comply with the ordinance, from 3 to 5 millions of dollars will be required. If they comply with the ordinance as independent operating companies who have no right to interconnect their conductors, then the cost will be from 15 to 20 million dollars.

I mention this case simply to illustrate the advisability of co-operation between the various utilities in any one community.

Mr. C. J. Wilson, San Francisco: I want to add a point on the subject of junction boxes, which was touched on in the Report, particularly the junction boxes used on the high-tension end of a system. The low-tension end of the system, that is the secondary, is very similar in a great many respects to the older system, the continuous-current system, and for this reason a great many junction boxes have been developed which will serve the purpose for the secondary end of the system. However, on the primary or high-voltage end very little development has been made except by the operating companies themselves, and this for their own protection and for the reason that there were no suitable forms of junction box available on the market.

The company with which I am connected has carried on this development to a considerable degree and we have had very great success with junction boxes operating on voltages up to 4000, 3-phase, with 2300 volts to ground. I understand that now several of the manufacturing companies have taken this subject up and are developing boxes which are suitable not only for secondary low-tension work, but also for higher voltages. Within a year there should be boxes on the market which will answer every requirement for alternating-current distribution.

There is one other point I should like to mention, and that is the matter of records. Every company installing an underground system should start a complete and accurate record of all the construction and material that go into the system, keeping not only physical but historical records and a record of the performance of the cables and other apparatus used in connection with the system.

In the matter of electrolysis the "drainage system" seems to be the best solution of the trouble, the application of which system depends, of course, on the co-operation of the companies whose apparatus is involved. The question of bonding cables and railway returns to gas mains is not entirely satisfactory to the

gas companies, but in a great many cases they can be prevailed upon to accept the arrangement, providing all the other companies get together and agree upon this solution.

MR. ELDEN: May I add one word in line with cable temperatures? I found a year ago that in England it is customary to operate transmission cables continuously at temperatures around 150 degrees Fahrenheit without damage to the cable, and I believe at the present time American manufacturers, under certain specifications, will furnish a paper-insulated cable which can be operated at these temperatures without damage. In American practise the manufacturers of certain types of 3-conductor, 4/0 cables allow a carrying capacity of 211 amperes per conductor, yet we find under operating conditions they can be easily worked at 250 amperes for a long time without developing temperatures that are at all dangerous.

MR. ABBOTT: Mr. Elden brought out some points which seem to require comment from the Committee. He recommends two-part manholes for the housing of transformers. The adoption of two-part manholes for set-off mantles of cable or transformer boxes is desirable, but not from the point of view of cost, and it is frequently impossible to make such an installation by reason of the condition of the street.

Mr. Elden apparently did not understand the reference to a 10-volt drop. The paragraph in which that phrase occurs reads as follows: "Some calculations made recently in one large city indicated that the total cost of additional feeder copper for the purpose of reducing the maximum drop in the tracks," etc. That is, the maximum track drop between any two points will be 10 volts and not the difference of potential between cables and tracks.

MR. ELDEN: Would not that difference of potential exist between the ends of cable sheaths running parallel to the tracks?

MR. ABBOTT: Oh, it is bound to work more damage over the distance in which that would occur. It would take a considerable length of track to accumulate a drop in potential of 10 volts.

The Committee regrets that there was such a dearth of information from the companies to whom questions were sent regarding the carrying capacity of the cables. The data submitted were extremely meagre and varied widely.

In regard to Mr. Wilson's inquiry as to junction boxes, the Committee has failed to discover any good form of high-tension

junction box, and is further of the opinion that a thoroughly first-class, high-tension junction box would be an extremely expensive device and would require so much space as to make its installation very difficult.

The Committee also noted in the questions received from member companies that there were a considerable number of complaints regarding the high-tension fuses used in subways, and although one company reported a high degree of success with the use of a certain coil and fuse, the Committee has not sufficient information to make a recommendation along this line.

The Committee wishes to express its appreciation, particularly to Mr. Elden, for the very complete discussion which he has given the Report. [Applause.]

THE CHAIRMAN: We will now listen to the paper of Mr. W. M. McConahey, Pittsburgh.

CARE AND OPERATION OF TRANSFORMERS

Large high-voltage transformers such as are now generally used for power transmission require a reasonable amount of care in order that they may give satisfactory service. It will not do to install such transformers and put them into service and then expect them to operate year in and year out with practically no further attention. The larger the size, and particularly the higher the voltage, the more important it becomes that careful and intelligent inspection be provided.

Within a very few years the sizes of units and voltages of transmission have increased greatly, so that a few suggestions on the care and operation of transformers should be of value to operating men. It is the intention of this paper to deal mainly with oil-insulated transformers, although many of the points brought out will apply equally to the air-blast type.

There are two essentials to be considered in the design of transformers, namely, insulation and heating. There are minor points to be taken into account, such as efficiency, regulation, adaptability to various classes of service, etc., but the only practical effect they have is to modify the proportions of the design. The insulation must be of good quality, of sufficient amount, properly distributed, and the provisions for ventilating the windings and dissipating the heat must be such as will keep the temperature within reasonable limits. Assuming that these conditions have been met by the manufacturer, it is seen at once that the operating man must do his share towards maintaining the insulation in good condition and preventing excessive heating by prolonged heavy overloads. With intelligent and systematic care, there is practically no end to the life of a well-designed modern transformer.

The principal insulating material used in transformer manufacture, known as "press-board" or "fuller-board," is of a fibrous nature. It is made up in large sheets varying in thickness from a few mils to about ⅛ of an inch, although in large transformers it is generally not used in thickness of less than 1/16 of an inch. It is cut and formed into the proper shapes and assembled with the coils so as to give the necessary dielectric strength in the various parts. From this it is seen that the fuller-board is

depended upon to furnish the insulation among the various parts of the windings and between the windings and ground, and that it must be maintained in good insulating condition if

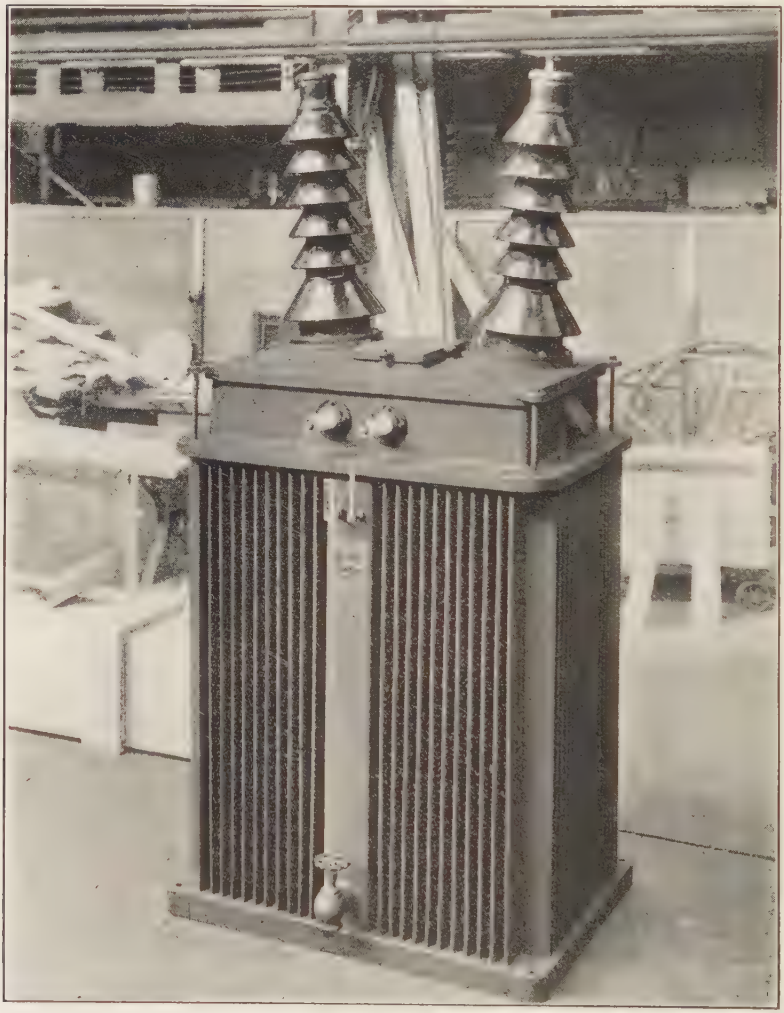


FIG. 1—150-KVA, OIL-INSULATED, SELF-COOLING, OUTDOOR TRANSFORMER 66,000 TO 2300 VOLTS

the transformer is to have long life and continue to operate without giving trouble,

Since fuller-board is of a fibrous nature, it has a tendency to absorb moisture wherever it is present. Unfortunately, the more moisture that is absorbed the weaker becomes the dielectric strength. No satisfactory method has yet been devised for treating the fuller-board so as to make it entirely impervious

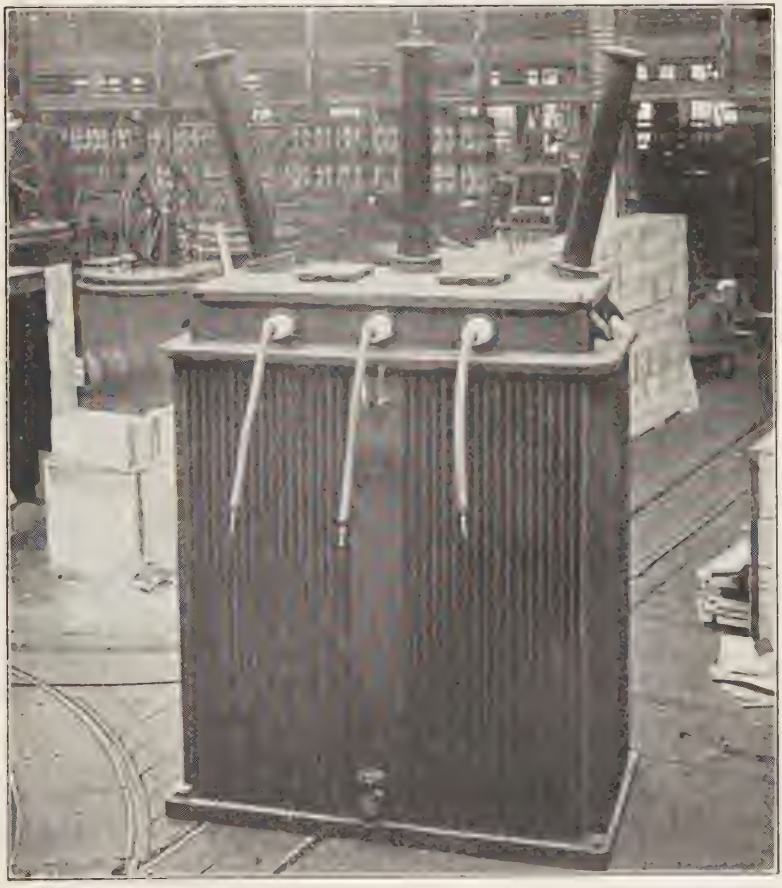


Fig. 2—300-Kva, Oil-Insulated, Self-Cooling Transformer, Three-Phase, 88,000 to 24,000 Volts

to moisture, nor has any satisfactory substitute been found that will meet the requirements. It is necessary, therefore, in order to protect the insulation to use such means in operation as will prevent as much as possible the entrance of moisture into the

transformer case and to remove any that may enter before it has had time to cause serious trouble.

Formerly it was customary to ship transformers packed separately from their tanks. When shipped in this manner it was practically impossible to prevent the insulation from absorbing moisture, even when special methods of packing were resorted to. Such schemes as packing in tin-lined cases or placing calcium-chloride inside of packing cases never proved very satisfactory, so that before putting a transformer into service it was nearly always necessary to dry it out. This required time and care and a certain degree of expert knowledge which made it

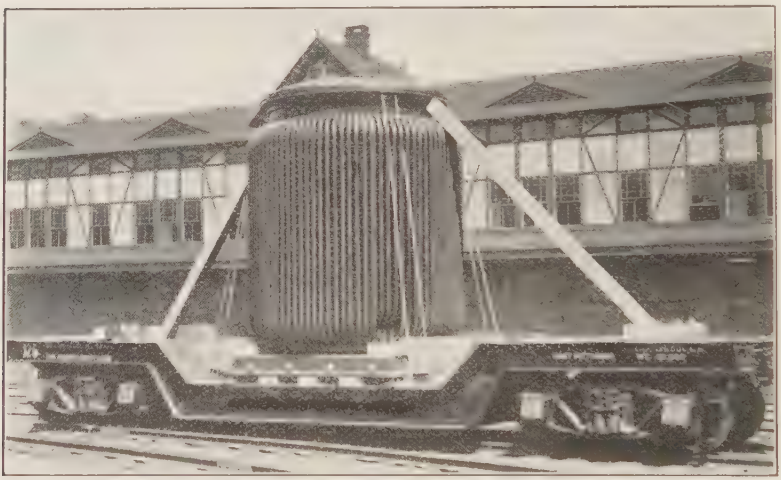


Fig. 3—2000-Kva, Oil-Insulated, Self-Cooling Transformer, 100,000 to 50,000 Volts

very desirable that some method of shipment be devised which would make drying out before installing unnecessary. This is now accomplished by bracing the transformer securely in its tank, filling the tank with oil and shipping in this manner. The only limit imposed upon this method of shipment is the inability of the railroads to handle very large sizes because of insufficient clearances. This has been overcome to a considerable extent by the use of a special form of "cut-out" car with the floor much lower than that of an ordinary flat car.

When a transformer is shipped in its own tank with the oil it should arrive at destination with the insulation and oil prac-

tically dry and free from moisture. In order to make sure of this, however, it is best to draw a few samples of oil from the bottom of the tank and test them. The best way to make the test is to use some standard form of testing cup and a variable ratio testing

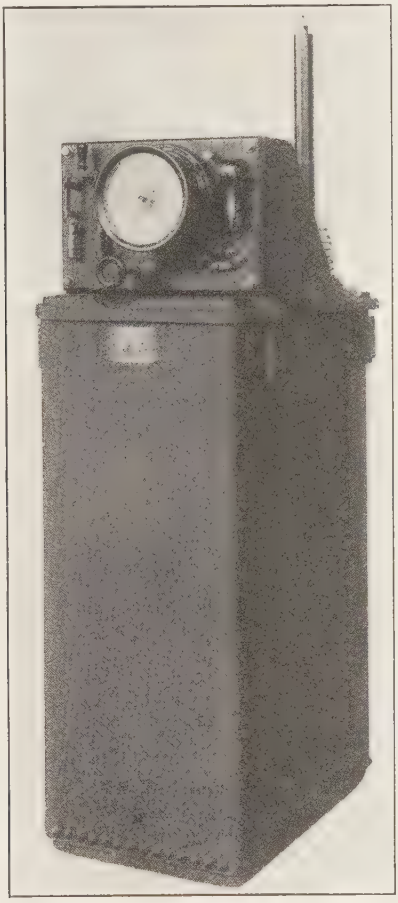


Fig. 4—7½-Kva, Variable-Ratio, Testing Transformer, 0 to 50,000 Volts

transformer by means of which the voltage can be raised gradually. The cup is filled with a sample of the oil, the gap is adjusted to a fixed length with a micrometer screw and the voltage is raised until a spark jumps across the gap through the oil. It is customary to set the gap at about 150 mils, and with such a setting good oil will show break-down of not less than

30,000 volts, *i. e.*, 200 volts per mil of gap for an average of ten tests. A variable ratio testing transformer may not always be available, but any company using transformers should not be without an oil-testing cup, which is an inexpensive piece of apparatus. If no means of varying the voltage is at hand, so that it is necessary to use a fixed voltage for making the test, the gap should be set to give 200 volts for every mil of separation and break-down should not occur at this setting. In making tests

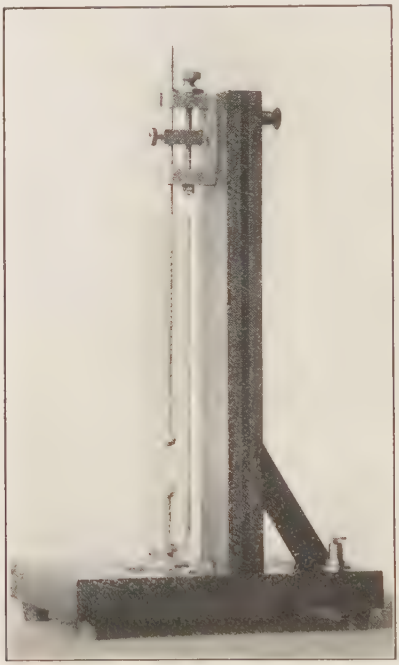


Fig. 5—Oil-Testing Cup

in this way, however, it is not advisable to use a testing voltage below 6600 volts. If the tests on samples of oil taken from the transformer shipped in its tank with the oil are satisfactory, it is a practically sure indication that the transformer is dry and ready to put into service.

Cleanliness is essential to good service, and it is important for the life of the transformer, particularly if it be of high voltage, that the tank be closed up tightly so as entirely to exclude dust and dirt. This is done by packing tightly around all

outlet bushings and placing gaskets under the cover, and also under hand-hole and man-hole covers. In very large transformers the gaskets are often made so that the tank can be closed up practically air-tight, but in medium and small sizes the gaskets are generally made of felt or hemp treated with a

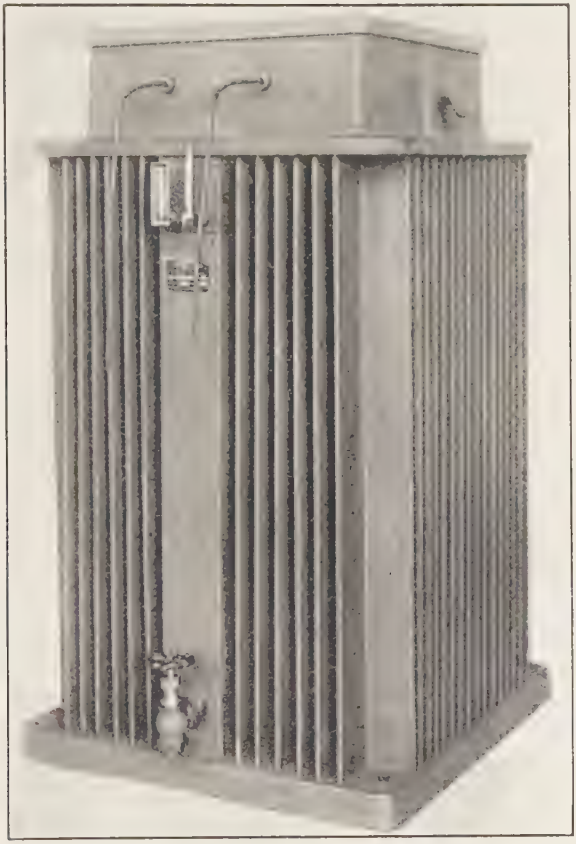


Fig. 6—Standard Oil-Insulated, Self-Cooling Transformer

moisture-proof compound. It is surprising how much dirt can gradually work its way through a very small crack, so that it should not be taken for granted that small openings are harmless. To allow a transformer to operate with a loose-fitting cover or with openings unclosed is inexcusable negligence which will be paid for by a shortened transformer life.

FIG. 7– 40-KVA, OIL INSULATED, SELF-COOLING OUTDOOR TRANSFORMER, 44,000 TO 2300 VOLTS

After the transformer has been installed and put in operation successfully, it should not be expected to operate continuously thereafter without further attention. A periodical inspection should be made about once every six months. Such an inspection should include a test of a sample of the oil drawn from the *bottom* of the tank and an examination of the interior. If a test of the oil shows the presence of too much moisture, or an inspection shows a deposit of dirt or slime in the transformer, the oil should be drawn off and filtered and dehydrated, and the transformer and interior of the tank should be thoroughly cleaned with dry clean waste. The ventilating ducts can generally be cleaned by squirting dry oil through them. If the transformer is water-cooled the cooling coils should be examined to find out whether any deposit has been formed on them by the oil. Some oils will form a coating on the cooling coils which acts as a heat insulator and causes the transformer to run hot. This deposit can be removed only by scraping and rubbing the coils until they are clean. Good transformer oils, as they are supplied to-day, will form little or no deposit. They are also reasonably clear, so that by the use of an incandescent lamp a very good inspection of the upper part of the windings can generally be made without the necessity and inconvenience of lowering the oil until the coils are exposed.

If the oil in a transformer is found to be in a dirty condition or to be forming a deposit, it should be filtered, and if it is found to contain moisture, steps should be taken at once to remove this moisture. The filtering process can be performed easily by passing the oil through two or three thicknesses of bolting cloth. One passage through the cloth will nearly always be found sufficient to remove all the dirt or deposit.

The removal of moisure is not such an easy task. Various make-shift schemes have been tried from time to time but all of them are far from satisfactory. Some of these schemes are: Placing bags of dry lime in the oil, passing hot air through the oil, or heating the oil so as to vaporize the moisture and drive it off.

In order to remove the moisture completely and leave the oil in first-class condition, it should be passed through some standard form of dehydrator designed particularly for that purpose. Probably the best form of this class of apparatus is

that known as the filter-press type. In this type the oil is pumped through several thicknesses of a specially prepared paper. The paper has the peculiar faculty of allowing the oil to pass through freely, while at the same time retaining every bit of moisture until it becomes saturated. When the paper approaches saturation, it should be removed and replaced by fresh dry paper. This is the best method that has yet been devised for removing moisture from oil. It is very simple and removes the moisture entirely, leaving the oil in a clean, dry condition.

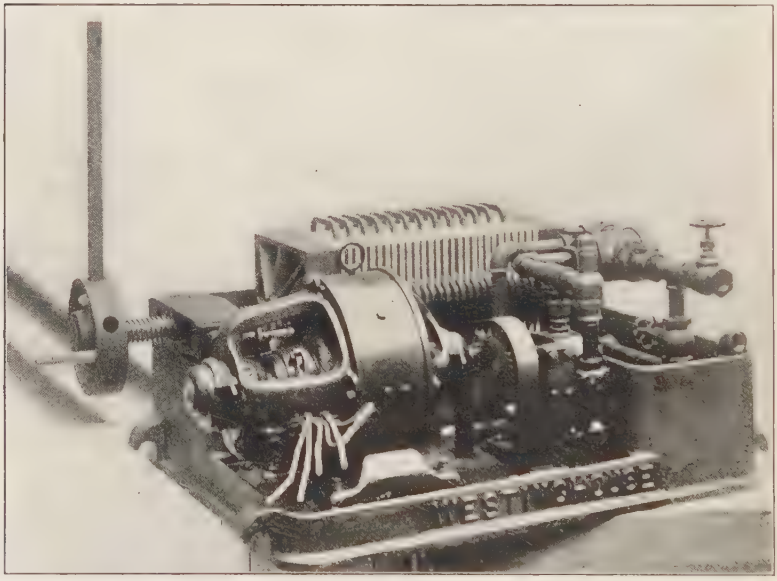


Fig. 8—Oil-Dehydrating Outfit, Filter-Press Type

An exceedingly simple and satisfactory way of keeping the oil clean and dry is to connect a small dehydrator outfit to a transformer tank in such a way that the oil can be pumped from the bottom of the tank through the dehydrator and back again into the tank at the top. The connection at the bottom can be made through the oil-valve which is provided with all transformers. The necessary connections can be made and the dehydrator put into service without in any way interfering with the operation of the transformer. A small, cheap dehydrator

having a capacity of about two gallons per minute can be had which is particularly suitable for this work. It can be kept in operation continuously until the oil is clean and dry. This method of caring for the oil should appeal to operating men because of its simplicity and convenience.

Assuming that the necessary care is taken to keep the transformer clean and dry, it is equally important that it be not

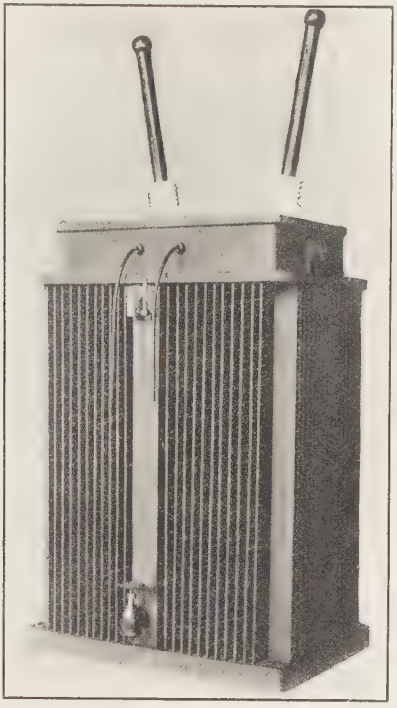


FIG. 9—200-KVA, OIL-INSULATED, SELF-COOLING TRANSFORMER, 66,000 TO 2300 VOLTS

overloaded to such an extent that the insulation is damaged by excessive heating of the coils. Insulation will not stand prolonged heating at a temperature much above 100 degrees C. without permanent injury.

It is practically out of the question to determine the actual temperature of the copper, which is the hottest part, so that about the only guide the operating man has is the temperature of the oil. It is generally customary for manufacturers to guarantee

that the temperature rise of the windings of power transformers when operating at normal load will not exceed 40 degrees C. above the temperature of the cooling medium (air or water). Going a little further and analyzing this 40 degree drop, we find that it may be divided up approximately as follows: Copper to oil, 10 degrees, and from oil through the tank to the air or from the oil through the cooling coil to the water, 30 degrees. These drops will vary considerably with different transformers, but the figures given represent a fair average. Assuming that the iron

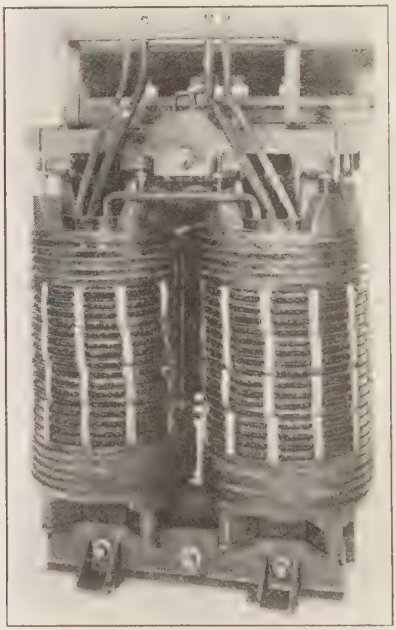


Fig. 10—200-Kva, 66,000 to 2300-Volt Transformer, Out of Case

loss and copper loss are equal, if the load is increased 25 per cent the copper loss will be increased 56 per cent while the iron loss will remain constant, so that the total loss will be increased 28 per cent. Roughly speaking, the different drops will be proportional to the amount of heat taken away, so that the drop from copper to oil for 25 per cent overload will be increased 56 per cent and that through the oil to the cooling medium 28 per cent. Applying these increases, we find that the normal load drops of 10 degrees from copper to oil and 30 degrees from oil

to cooling medium are increased to approximately 15½ degrees and 38½ degrees respectively, or a total of approximately 54 degrees. That is, increasing the load 25 per cent has increased the temperature rise of the windings from 40 degrees to 54 degrees. The standard temperature guarantees for power transformers when operating continuously at 25 per cent overload is 55 degrees.

If the windings are well ventilated the maximum temperature will not exceed the average by more than a small amount, but if they are poorly ventilated there may be a wide difference between the maximum and average temperatures. From the above discussion it will be noted that as the load is increased the drop from copper to oil increases rapidly, so that for heavy overloads the temperature of the copper is much above that of the oil. For this reason, if it is necessary to put a heavy overload on a transformer for several hours, some judgment must be exercised in trying to determine from the temperature of the oil what the temperature of the windings is. If this temperature (not temperature rise) is allowed to get much beyond 100 degrees C., there is danger of the insulation being permanently injured.

There is quite a difference between a prolonged overload and one of short duration. Oil has the capacity of storing considerable heat, so that if a transformer is operated at a moderate temperature, quite a heavy overload can be thrown on suddenly and carried for such a time as is required to raise the oil to a temperature beyond which it is not safe to go because the temperature of the windings has approached the limit of safety. The thermal capacity of oil is such that one kw will raise the temperature of 11 gallons 1 degree C. per minute. Setting this in the form of an equation we have $t = \frac{11 \times KW \times T,}{G}$ in which t = temperature in degrees C., kw = loss, T = time in minutes and G = gallons of oil. During the time that heat is being stored in the oil it is also being taken up by the circulating air if the transformer is self-cooling, or by the cooling water if water-cooled. While the transformer is being heated up under a steady load, the rate of storing heat gradually decreases and the rate of giving up heat to the cooling medium gradually increases until finally a steady condition is reached in which no heat is stored up but all is given to the cooling medium. During the heating-up process

if the transformer is under heavy overload the temperature of the oil should be watched and should not be allowed to exceed a value which, according to the approximate method given above

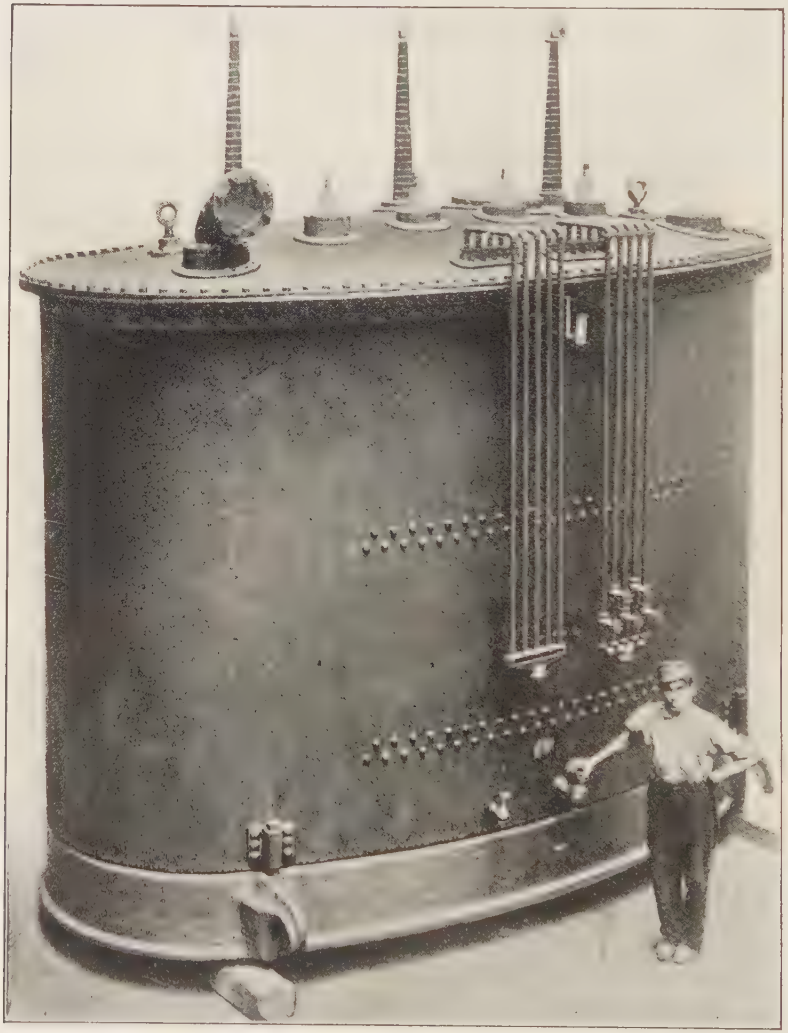


Fig. 11—10,000-Kva, Oil-Insulated, Water-Cooled Transformer, Three-Phase, 60,000 to 13,200 Volts

for calculating temperature drop through the copper and oil, indicates a winding temperature exceeding 100 degrees C.

Self-cooling transformers can now be built in sizes up to about 2000 or 3000-kw, depending upon the voltage and frequency. These large sizes are particularly applicable where it is desirable to transform large amounts of power without artificial cooling and with a minimum amount of attendance.

The output for which water-cooled transformers can be built is limited only by the weight and the mechanical dimensions

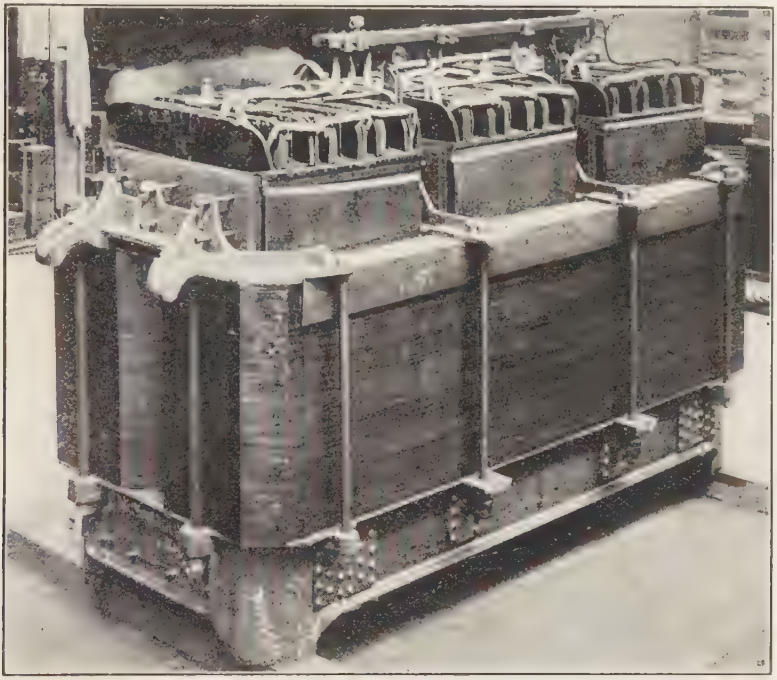


FIG. 12—10,000-KVA, 60,000 TO 13,200-VOLT, THREE-PHASE TRANSFORMER, OUT OF TANK

which make handling or transportation difficult. In very large sizes, it is sometimes necessary to ship the transformer in a more or less knocked-down condition and assemble the parts at destination. The reason that water-cooled transformers can be built in such large sizes is that cooling coils with sufficient radiating service to take care of the large amounts of heat generated can be made without trouble.

Water, because of its very high thermal capacity, is particularly suitable as a cooling medium. One kw will raise 3.8

gallons of water 1 degree C. in one minute. Ordinarily the water rate is ¼ gallon per minute per kw-loss, which gives a temperature rise of 15 degrees C. from the inlet to the outlet of the cooling-coil.

Fig. 13—4000-Kva, Oil-Insulated, Water-Cooled Transformer, 100,000 to 50,000 Volts

Increasing the water rate decreases its temperature rise in inverse ratio and the temperature of the windings is lowered approximately one-half the amount by which the temperature

rise of the water is lowered. On the other hand, decreasing the water rate increases its temperature rise in inverse ratio and the temperature of the windings is raised approximately one-half the amount by which the temperature rise of the water is increased. As an example, if the water rate is increased from ¼ to ⅜ of a gallon per kw-loss, the temperature rise of the water

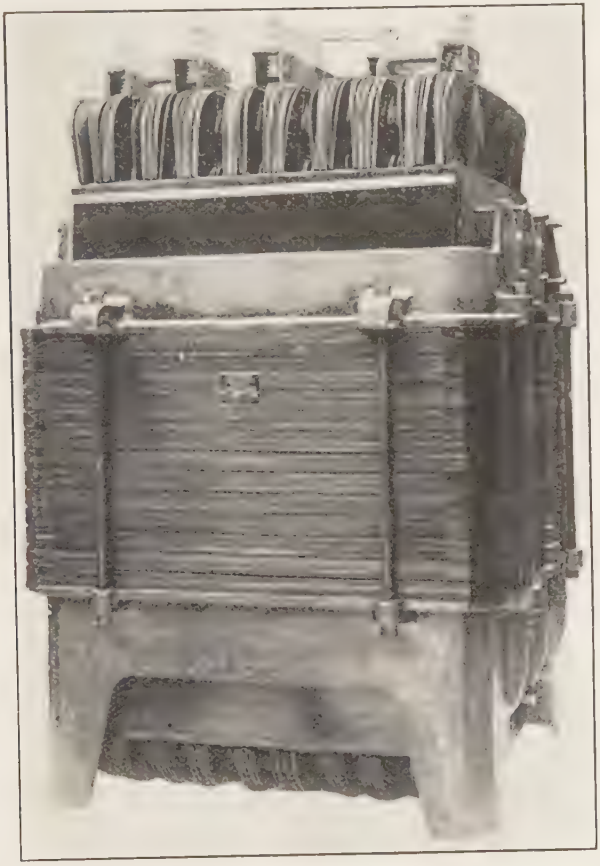


Fig. 14—4000-Kva, 100,000 to 50-000-Volt Transformer, Out of Tank

will be decreased from 15 degrees C. to 10 degrees C. The average temperature of the water in the cooling coil is 2½ degrees lower for the ⅜-gallon rate than for the ¼-gallon rate, and therefore the temperature of the windings is also 2½ degrees lower. Thus it is seen that no very great gain is made by

increasing the water rate. If, however, a heavy overload is placed on the transformer so that the temperature rise of the water is considerably increased, an increase in the water rate will help materially.

Some kinds of water will gradually form a deposit on the inside of the cooling coil which will act more or less as a heat insulator, and may in extreme cases close up the opening in the coils entirely. The presence of this deposit can be detected by a decreased flow and an increased temperature rise of the water or by an increase in the temperature of the transformer. It can generally be removed by passing a solution of hydro-chloric acid through the cooling coils.

A water-cooled transformer should not be operated except for a very short time without the circulation of water through the cooling coils. The transformer will heat up very rapidly and will soon reach a dangerous temperature. It cannot even be operated in this manner for any length of time without load, because the iron loss in itself is sufficient to raise the temperature above the danger point. In order to guarantee against overheating due to the stoppage of the flow of water, it is customary to equip water-cooled transformers with alarm contact thermometers, to which alarm bells can be wired for the purpose of giving warning if the temperature should rise too high.

We will now say a few words about air-blast transformers, which form a class by themselves. Their use is comparatively limited, being confined chiefly to a few large centers. For cooling purposes there are required about 150 cubic feet of air per minute per kw of loss. The air pressure required varies from about ½ to 1 ounce, depending upon the size of the transformer. If the air-pressure is shut off from an air-blast transformer it can carry full load for only a few minutes before reaching a dangerous temperature. This will be understood easily when it is remembered that there is no oil to store heat, and since there is very little radiation, practically all the heat generated in the windings has to be stored in the copper. The thermal capacity of copper is very low, and therefore it heats up very rapidly.

Starting cold and throwing on full load, with the air-blast going, an air-blast transformer will reach steady temperature conditions in about two hours, while an oil-cooled transformer would require probably six to ten times as long. Because of the

rapid heating-up of the windings, an air-blast transformer cannot safely carry a heavy overload for more than a few minutes. The temperature rise of the windings under normal operation varies approximately in the same ratio as the copper loss. For example, if the temperature rise is 35 degrees C. under full

Fig. 15—750-Kva, Air-Blast Transformer

load, it will be approximately 55 degrees C. at 25 per cent overload.

This type of transformer should not be wound for voltages exceeding about 35,000 volts. Beyond this it is impractical to go because of the insulation difficulties encountered.

When two or more transformers are to be operated in parallel or in banks on a polyphase circuit, it is necessary to know their polarity in order that they may be connected up properly. If all of the transformers are alike, they may have the same polarity, but if some of them are of different design or were made by different manufacturers, their polarity may be different.

The polarity of a single-phase transformer is very easily determined. In Figure 16, let A and B be the high-tension

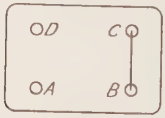


Fig 16

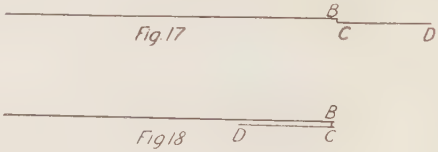


Fig 17 Fig 18

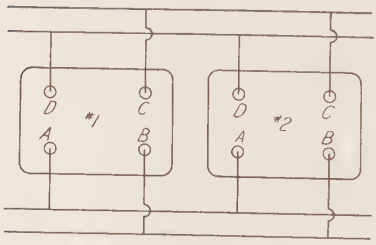


Fig 19

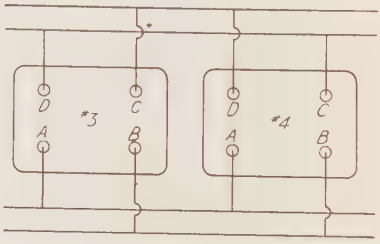


Fig 20

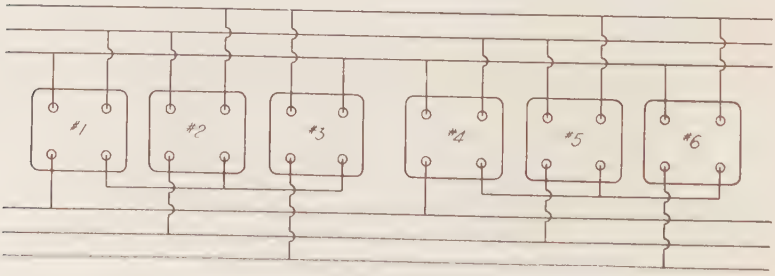


Fig 21

FIGS. 16, 17, 18, 19, 20 and 21

terminals and C and D the low-tension terminals. Connect B and C together and impress some convenient voltage across either A-B or C-D. Then measure voltages A-B, C-D and A-D. Now, since the transformer is single-phase, the voltages reckoned in the directions from A to B and D to C must either be in phase or in opposition, that is, 180 degrees out of phase. If the

voltage across A-D is the sum of those across A-B and C-D, the phase relation is shown in voltage phase diagram, Fig. 17, and the polarity, for want of a better name, may be called positive. If the voltage across A-D is the difference between A-B and C-D, the phase relation is shown in voltage phase diagram Fig. 18 and the polarity is negative.

If two single-phase transformers, both having positive polarity or both having negative polarity, are to be operated in parallel, they should be connected together in the ordinary manner as shown in Fig. 19. But if one has positive polarity and the other negative, then they should be connected together as shown in Fig. 20. This will be understood by reference to Figs. 17 and 18. Counting voltages from left to right as in the positive direction A to B and C to D (Fig. 17) are in the positive direction for positive polarity, while for negative polarity (Fig. 18) A to B is positive and C to D negative. If, however, we reverse the connections of C to D, we have D to C in the positive direction. If, therefore, we wish to connect a single-phase transformer of negative polarity in parallel with one of positive polarity, it is necessary to reverse the connections of either the high-tension winding or the low-tension winding of one of the two transformers as shown in Fig. 20.

Single-phase transformers connected in banks on three-phase circuits are simpler to deal with than three-phase transformers. Three-phase polarity is much more complicated than single-phase, because there are a large number of voltage phase combinations possible, some of which can be made to operate together while others cannot.

Fig 21 shows a standard star-delta connection with six single-phase transformers in two parallel banks, the polarity of No. 6 being the reverse of that of the other five. If the polarity of all six transformers were the same, No. 6 would be connected in a manner similar to No. 3 instead of having the connections of one winding reversed. If the polarity of all the transformers is the same, all banks should be connected to the line in an exactly similar manner. It is possible to connect one bank differently from the others and still secure parallel operation, but this is not advisable, because it is liable to lead to confusion and trouble. It is best to adopt one scheme of connection and adhere to it.

In a three-phase transformer the measurements necessary

to determine the polarity are made in a similar manner to those for single-phase. In Fig. 22, let A, B and C be the high-tension terminals and D, E and F the low-tension terminals of a three-phase transformer. Connect C and D together and impress any convenient three-phase voltage across either the high-tension or low-tension terminals. Then measure voltages A-B, A-C, B-C, D-E, E-F, D-F, A-E, A-F, B-E, B-F. The first

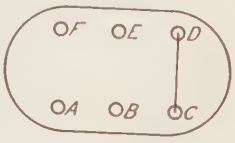


Fig 22

three of these voltages will of course all be equal and the 4th, 5th and 6th will be equal, the ratio of these two different sets of voltages being the ratio of transformation. The 7th, 8th, 9th and 10th voltages, that is, A-E, A-F, B-E and B-F, are the ones that determine the polarity. Now lay out a voltage phase diagram, remembering that since we are dealing with three-phase transformers we must be careful to note the phase position of the voltages as well as their values. As three-phase transformers are ordinarily designed, they may be connected delta high tension-delta low tension, or delta high tension-star low tension, or star high tension-delta low tension, or star high tension-star low tension, although the last one of these connections is very little used. The voltage phase diagram is different for each of these methods of connection, so that they will be dealt with separately.

We will consider first a transformer connected delta high tension-delta low tension. Let a, b, c, Fig. 23, be the voltage phase diagram of the high tension. Then any one of the six equilateral triangles of either Fig. 24 or Fig. 25 may represent the voltage phase diagram of the low tension; that is, there are twelve different polarity combinations possible. Now refer to Fig. 26, which shows the high-tension voltages in their phase relation to the low-tension combinations when C and D (Fig. 22) are connected together. A study of these diagrams will soon reveal the fact that certain voltage relations hold good for one particular combination that will not hold good for any of the other eleven. The following table gives a list of

voltage relations for each combination, since they are connected directly together.

POLARITY COMBINATIONS, THREE-PHASE TRANSFORMERS, DELTA HIGH TENSION-DELTA LOW TENSION

See Figures 24 and 25.

Combination	Voltage Relations			
1	af = be	af < ae	bf > be	af = ac — df
2	af = be	af > ae	bf > be	ae = ac — de
3	af = be	af > ae	bf > be	bf = bc + df
4	af = be	af > ae	bf < be	be = bc + de
5	af = be	af < ae	bf < be	ae = ac + de
6	af = be	af < ae	bf < be	bf = bc — df
7	af = be	af > ae	bf < be	ae = ac — de
8	af < be	af < ae	bf < be	af = ac — df
9	af < be	af < ae	bf < be	be = bc + de
10	af = be	af < ae	bf > be	bf = bc + df
11	af > be	af > ae	bf > be	af = ac + df
12	af > be	af > ae	bf > be	be = bc — de

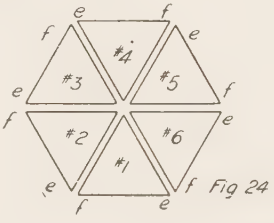


Fig. 24

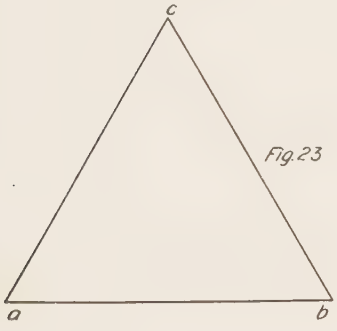


Fig. 23

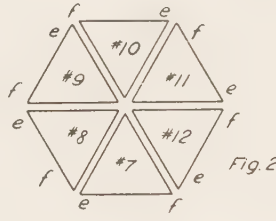


Fig. 25

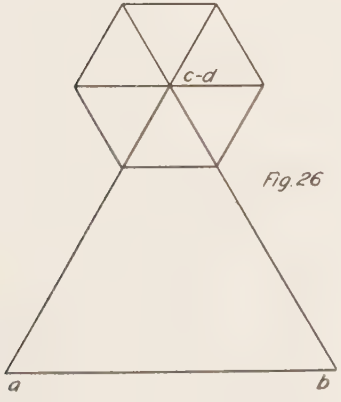


Fig. 26

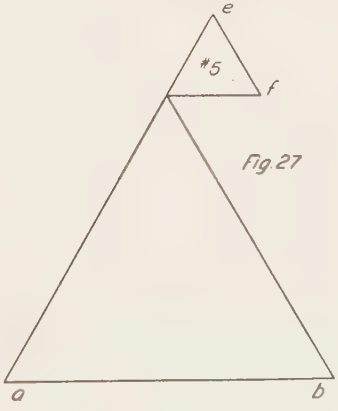


Fig. 27

Figs. 23, 24, 25, 26 and 27

With this table and the necessary voltage measurements the polarity diagram of any three-phase transformer connected delta to delta can be laid out in a few minutes.

Suppose the measurements are taken and compared with the table and combination No. 5 is found to apply. Then by referring to Figs. 24 and 25 the position of this combination is quickly located and the polarity diagram, Fig. 27, is easily laid out. This diagram should be laid out to scale. All angles are of course either 60 degrees or 120 degrees. After the diagram is drawn all the voltages should be scaled and they should correspond to the measurements taken on the transformer.

We will consider next a transformer connected delta on the high tension and star on the low tension. The measurements should be taken in the same manner as for the delta to delta connection.

Let a, b, c, Fig. 28, be the voltage phase diagram of the high tension. Then any one of the six groups of either Fig. 29 or 30 may represent the voltage phase diagram of the low tension, that is, there are twelve different polarity combinations possible. Now refer to Fig. 31, which shows the high-tension voltages in their relation to the low-tension combinations when C and D (see Fig. 22) are connected together. The following table gives a list of voltage relations that holds good for each of the twelve combinations.

POLARITY COMBINATIONS, THREE-PHASE TRANSFORMERS. DELTA HIGH TENSION-STAR LOW TENSION

See Figures 29 and 30.

Combination	Voltage Relations		
1	af = be	af = ae	bf > be
2	af = be	af > ae	bf > be
3	af = be	af > ae	bf = be
4	af = be	af = ae	bf < be
5	af = be	af < ae	bf < be
6	af = be	af < ae	bf = be
7	af < be	af = ae	bf < be
8	af < be	af < ae	bf < be
9	af < be	af < ae	bf = be
10	af > be	af = ae	bf > be
11	af > be	af > ae	bf > be
12	af > be	af > ae	bf = be

For example, suppose the measurements are compared with the above table and combination No. 8 is found to apply. Then by reference to Figs. 29 and 30 the position of this combination can be located and the polarity diagram, Fig. 32, laid out.

Consider next a transformer connected star on the high tension and delta on the low tension.

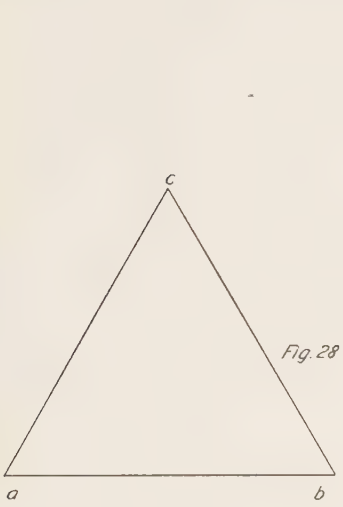


Fig. 28

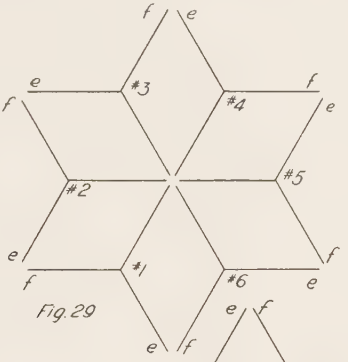


Fig. 29

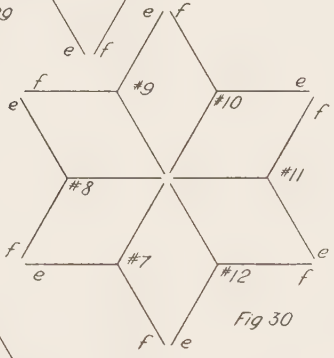


Fig. 30

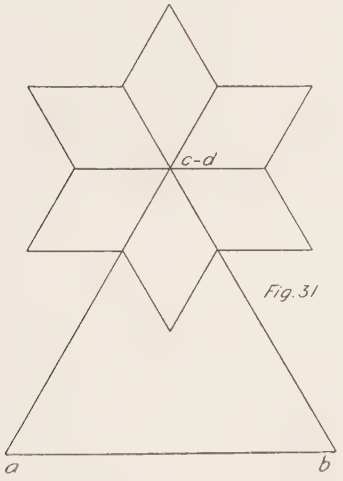


Fig. 31

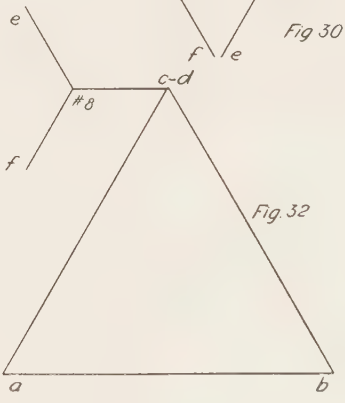
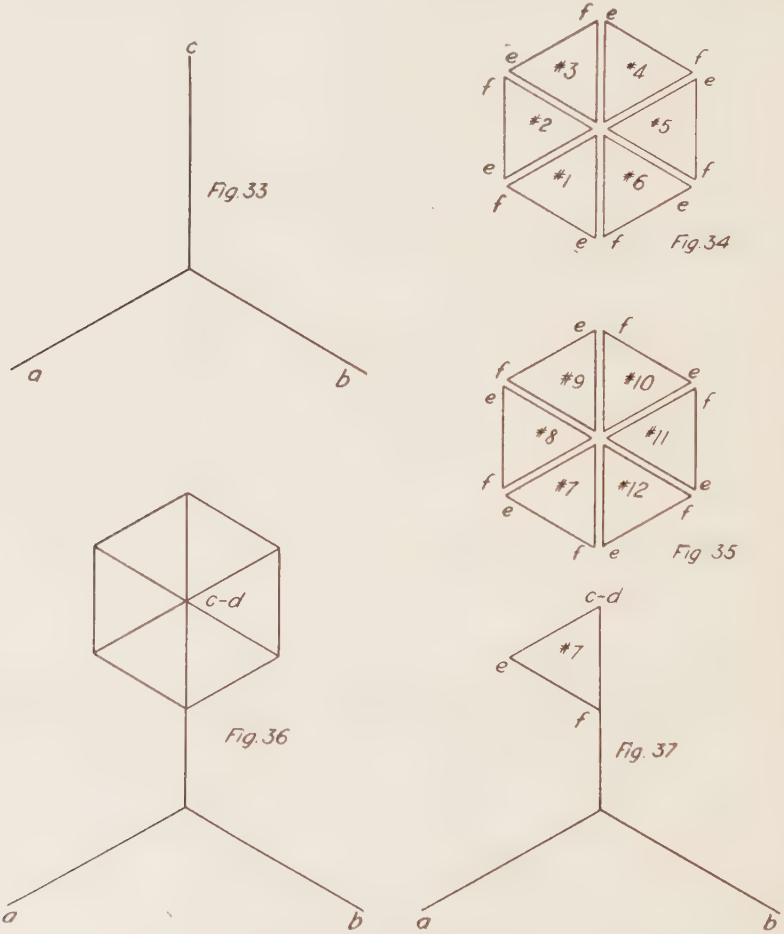


Fig. 32

Figs. 28, 29, 30, 31 and 32

Let a, b, c, Fig. 33, be the voltage phase diagram of the high tension. Then any one of the six groups of either Fig. 34 or 35 may represent the voltage phase diagram of the low tension, so that there are twelve different polarity combinations possible. Fig. 36 shows the high-tension voltages in their relation to the low-tension combinations when C and D are con-

nected together. The table on the following page gives a list of the voltage relations that hold good for each of the twelve combinations. It will be seen by comparing this table with the one given on page 680 that the two are identical. For example,



Figs. 33, 34, 35, 36 and 37

suppose the measurements are compared with the table and combination No. 7 is found to apply. Then by referring to Figs. 34 and 35 the position of this combination can be located and the polarity diagram, Fig. 37, laid out.

Transformers connected star on both the high tension and low tension will not be considered, because this is a connection rarely used.

POLARITY COMBINATIONS, THREE-PHASE TRANSFORMERS, STAR HIGH TENSION-DELTA LOW TENSION

See Figures 34 and 35.

Combination	Voltage Relations		
1	af = be	af = ae	bf > be
2	af = be	af > ae	bf > be
3	af = be	af > ae	bf = be
4	af = be	af = ae	bf < be
5	af = be	af < ae	bf < be
6	af = be	af < ae	bf = be
7	af < be	af = ae	bf < be
8	af < be	af < ae	bf < be
9	af < be	af < ae	bf = be
10	af > be	af = ae	bf > be
11	af > be	af > ae	bf > be
12	af > be	af > ae	bf = be

Comparing the three groups of combinations discussed above, it will be found that a transformer connected delta on the high tension to delta on the low tension cannot be made to parallel with one connected either delta on the high tension to star on the low tension or star on the high tension to delta on the low tension, but that a transformer connected delta on the high tension to star on the low tension can be made to parallel with some combinations of one connected star on the high tension to delta on the low tension. It will also be found that some combinations of one transformer cannot be made to parallel with some combinations of another transformer using the same type of connections for the two windings. For example, a transformer connected delta to delta may have a combination that will not parallel with another transformer connected delta to delta. By changing the internal connections between the coils, however, it will be possible to bring out the terminals in such a way that parallel operation can be obtained for all combinations.

Referring to Fig. 38, it can soon be determined whether two three-phase transformers have the same polarity by connecting them in parallel on the high-tension and low-tension sides, but leaving terminals E and F of transformer No. 2 disconnected. In making these connections similarly numbered terminals should be connected together, that is A-A, B-B, etc.* If, with this arrangement, there is no voltage between E and e or between F and f of transformer No. 2, the polarities are the same and the connections can be completed and the transformers put into service. If, however, there is found to be a difference of voltage between E and e or F and f, or both of them, the polarity of

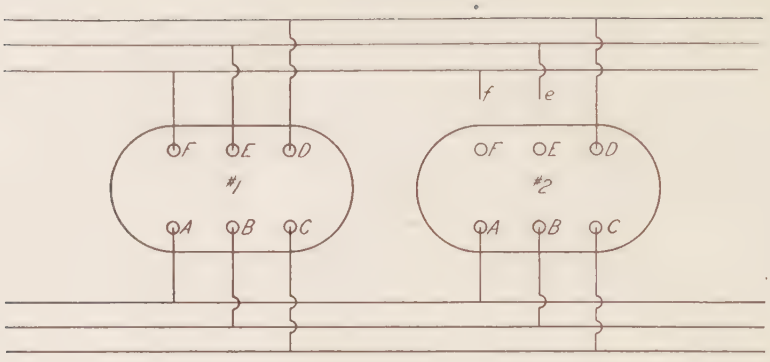
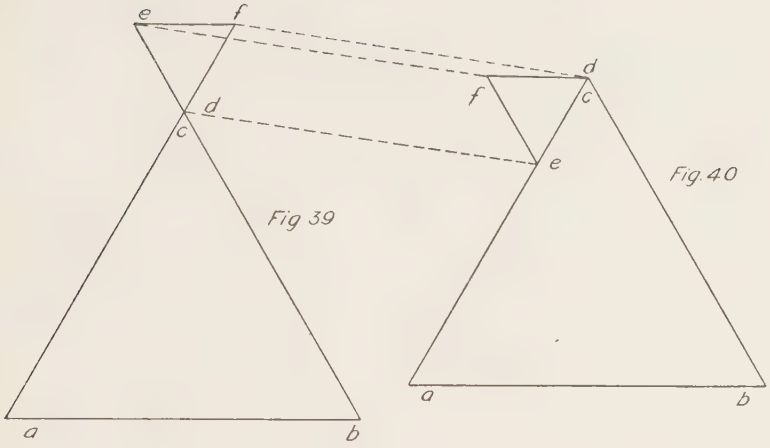


Fig 38

the two transformers is not the same. In this case the polarity of each transformer should be determined separately and the voltage phase diagram laid out to ascertain whether it is possible to arrange the connections in such a manner as to make parallel operation possible.

Suppose the voltage phase diagram of transformer No. 1 is shown in Fig. 39 and that of No. 2 in Fig. 40, the lines joining a and b, a and c, b and c of one diagram being exactly parallel to the corresponding lines of the other. Now it will be noted that if triangle d e f of Fig. 40 be moved in a straight line *without any rotation* and placed directly over triangle f d e of Fig. 39, then d of Fig. 40 will be exactly over f of Fig. 39, e of Fig. 40 over d of Fig. 39, and f of Fig. 40 over e of Fig. 39. This means that if the two transformers have their low tensions connected in such a manner as to join these corresponding terminals, parallel operation can be secured. Fig. 41 shows the correct connections.

In general it may be stated that if the voltage phase diagram of two transformers with the same high-tension and low-tension voltages be laid out in the same manner as shown in Figs. 39 and 40, and if the low-tension part of one diagram can be moved in a straight line *without any rotation* and placed over the low tension part of the other diagram so that the corners exactly correspond, then parallel operation is possible, but if the corners do not correspond, parallel operation is impossible. As examples, Figs. 42 and 43 show that parallel operation



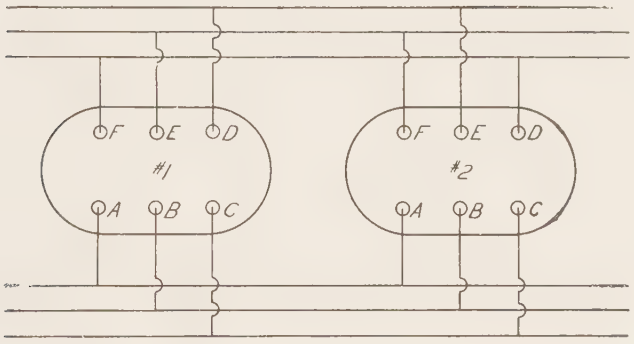


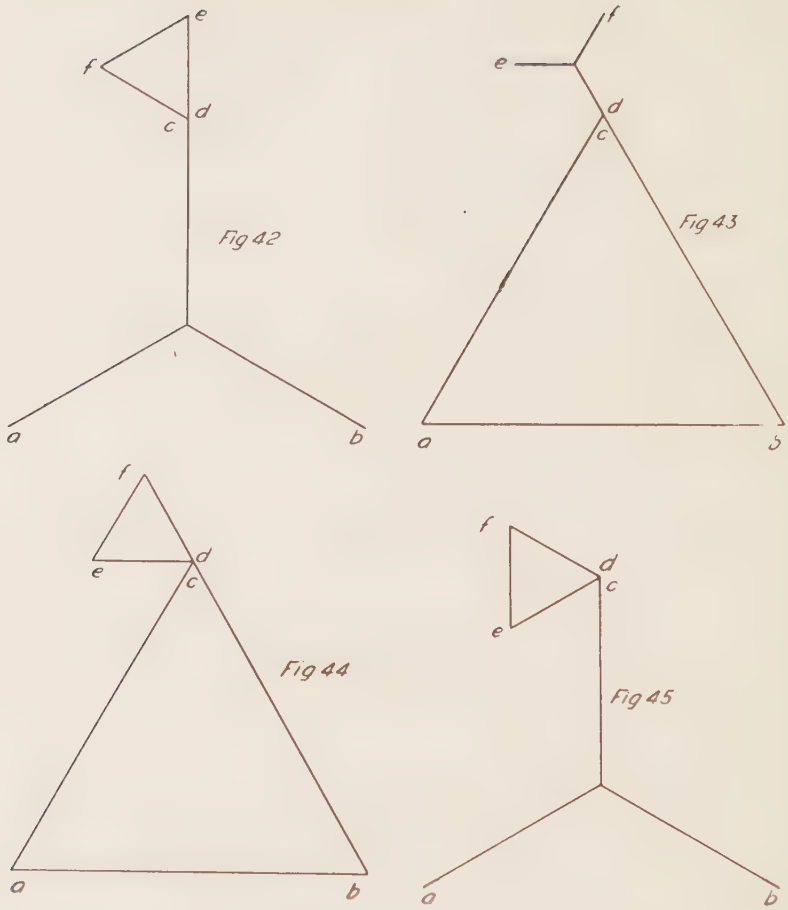
Fig. 41

FIGS. 39, 40 and 41

is possible, while Figs. 42 and 44 or 42 and 45 show that it is impossible.

By referring to Figs. 24 and 25 (page 679), it will be noted that any low-tension combination indicated by an odd number can be connected so as to parallel with any other odd-numbered combination but not with any even-numbered combination. The reverse is also true, that any low-tension combination indicated by an even number can be connected so as to parallel with any other even-numbered combination but not with any odd-numbered combination.

In order to secure perfect parallel operation between two transformers, they should have exactly the same ratio of high-



FIGS. 42, 43, 44 and 45

tension to low-tension turns, the same I.R. drop, and the same impedance drop. For all practical purposes, however, two transformers having the same ratio of turns and approximately the same impedance will operate satisfactorily in parallel even if the I.R. drops are different. Duplicate transformers will of course have the same characteristics and share the load equally. Two transformers of different make or different size will probably have different characteristics, so that when parallel operation is attempted, measurements should be made to determine if each will carry approximately its share of the load. As a general rule, transformers differing widely in size should not be operated

in parallel, particularly if the smaller size has much lower impedance than the larger. Where the impedances differ, the load on the transformer with the smaller impedance will increase and that on the one with the larger impedance will decrease until the two impedances become equal. For example, if a load of 400 kw be placed on a bank of two transformers, one of 100-kw capacity with 3 per cent impedance and the other of 300-kw capacity with 5 per cent impedance, the load on the 100-kw will be increased to approximately 145 kw, while the load on the 300-kw will be decreased to approximately 255 kw. In other words, the impedance of a transformer varies directly with the load, so that the load on the 100-kw transformer increases and that on the 300-kw decreases until the impedances become equal.

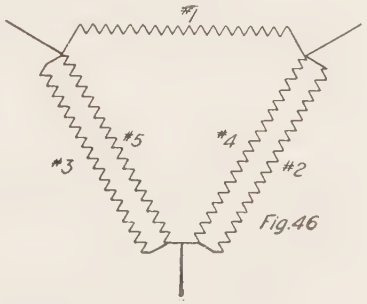


Fig. 46

It is not easy for manufacturers to design transformers to operate in parallel when the sizes differ widely and if tap voltages have to be considered the problem becomes much more difficult, the price may be increased considerably and the performances will probably not be as good as for a standard design.

When two transformers are connected in V on a three-phase circuit, the capacity is $1/\sqrt{3} = 58$ per cent of the capacity of three similar transformers connected in delta. This is due to the fact that for the delta connection the current and voltage of each transformer are in phase with each other, while for the V connection the current and voltage of each transformer are 30 degrees out of phase with each other.

When two transformers connected in V are operated in parallel with three transformers connected in delta, one of the transformers will take more than its share of the load. Such a connection is illustrated in Fig. 46, in which transformers

Nos. 1, 2 and 3 are connected in delta and operated in parallel with Nos. 4 and 5, which are connected in V. Without going into the theory it will be found that transformer No. 1 will be carrying normal load when each of the other four is carrying only 76½ per cent of normal load. It is evident, therefore, that when transformers operate in this manner, No. 1 must be watched carefully to see that it is not too heavily overloaded.

There are a large number of other interesting and useful polyphase combinations, but a discussion of them is beyond the scope of this paper.

(Adjourned.)

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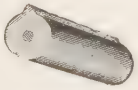

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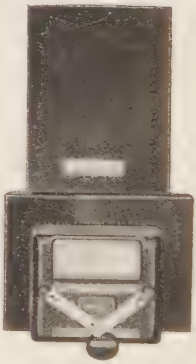

Fig. 2

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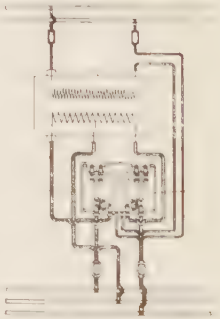

Fig. 3

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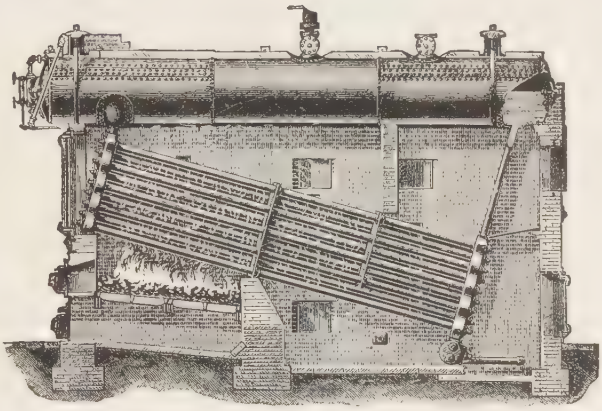

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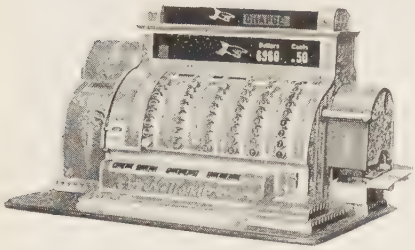

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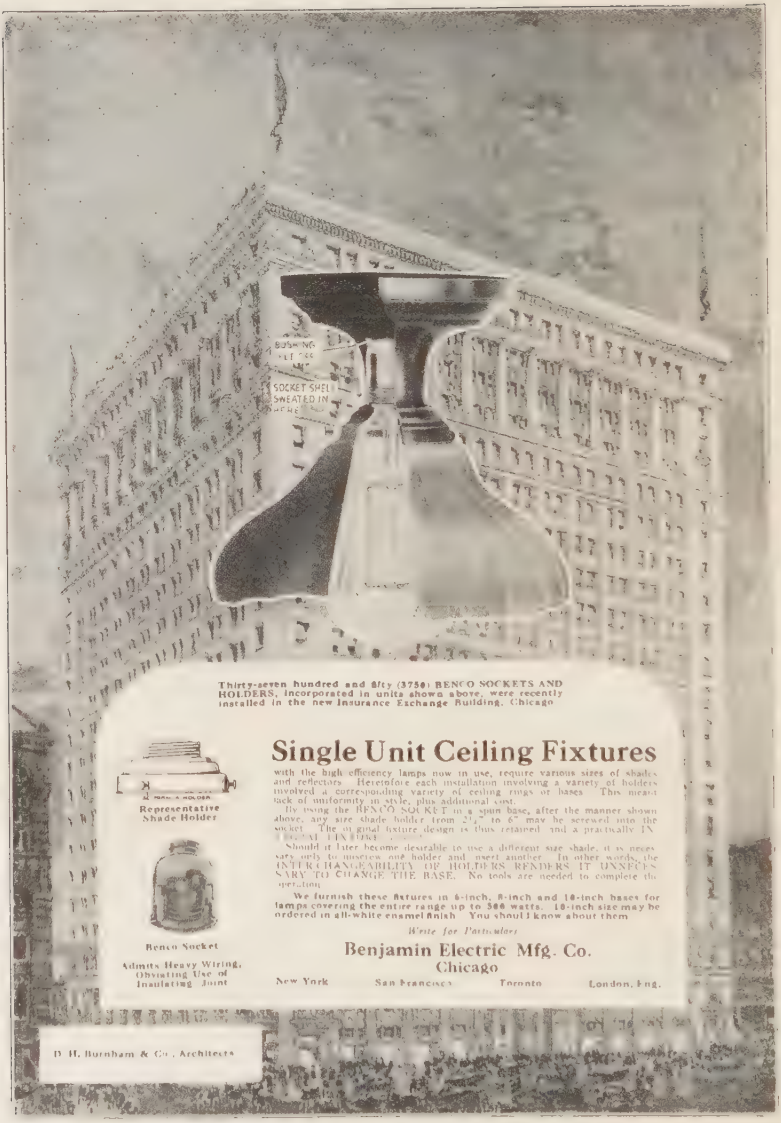

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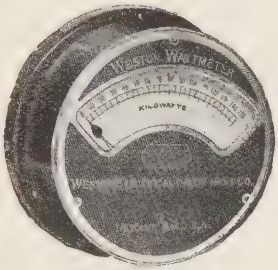

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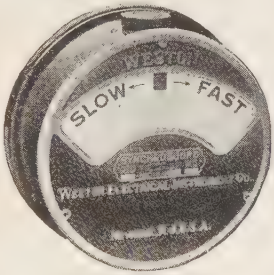

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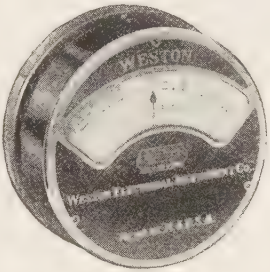

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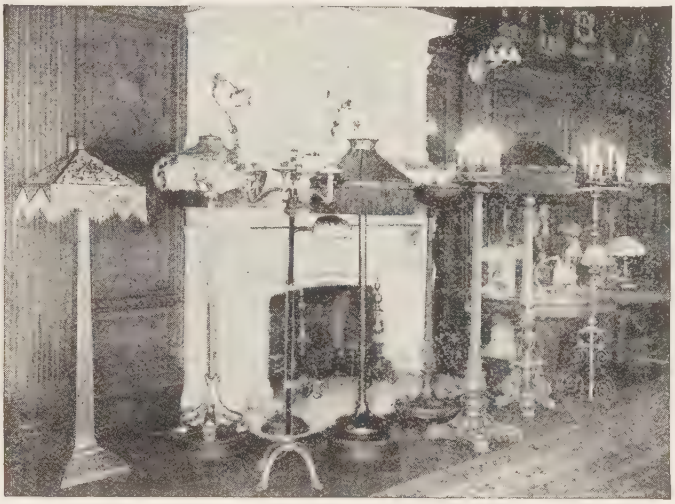

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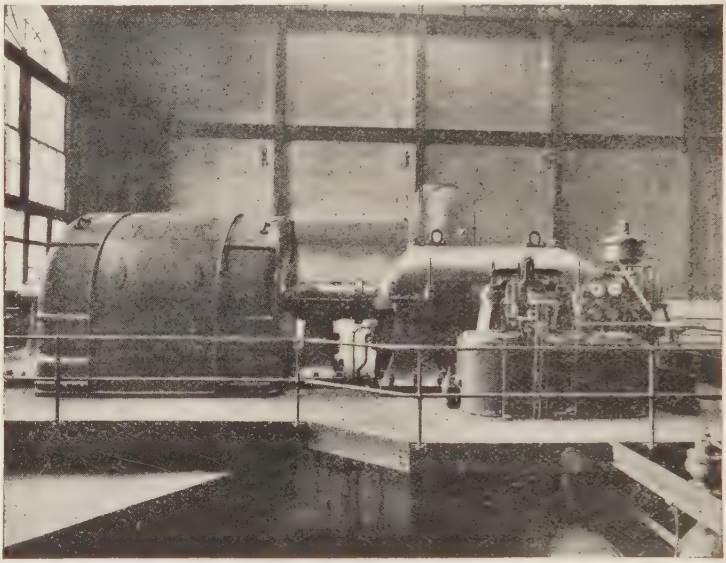

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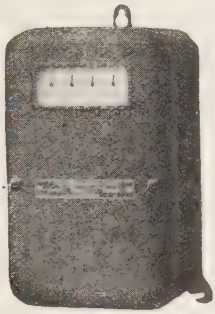

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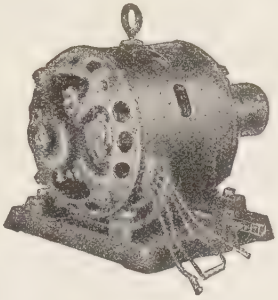

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